The Earth Observer

An EOS Periodical of Timely News and Events

Vol. 3, No. 7

November/December 1991

EDITOR'S CORNER

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LOOKING AHEAD TO 1992

1991 has been an eventful year for EOS, with reviews from the National Academy of Sciences and the External Engineering Review Committee, and directions from the Congress to design a program with greater resilience and flexibility that can adjust to changes in annual funding. In October the EOS Payload Panel examined these reviews and recommended a suite of instruments that focus on the troposphere, oceans, and land surface, monitoring of key gases in the stratosphere, and less emphasis on the upper atmosphere and the solid Earth.

We expect that Dr. Lennard Fisk, Associate Administrator for Space Science and Applications, will soon announce the payloads and schedules for the EOS satellites. The next issue of *The Earth Observer* will contain the full details.

Enjoy your holidays.

Jeff Dozier
EOS Project Scientist

PANEL REPORTS

Note to Readers:

At the August 1991 meeting of the EOS Investigators Working Group (IWG) in Seattle, plans were under way for the meeting of the Payload Panel that was to follow in October. In that regard, the EOS Program Scientist, Stan Wilson, asked that the EOS science panels provide payload recommendations that could be considered by the Payload Panel. At issue was the need to restructure the EOS program to maintain flexibility and accomplish scientific goals in the face of a considerably reduced budget. Wilson said that "we need IWG input to this process, in particular identifying a reduced set of EOS instruments that 'makes sense' and would constitute a scientifically justifiable payload for launch on/before 1998."

At the time of publication of this issue of ***The Earth Observer,*** *we have received copies of several written reports to the Payload Panel. Some are very lengthy; therefore, we are presenting summaries of them here. Others were shorter and are presented in full. At a later, date when all the reports have been received, we will publish them in their entirety in an EOS Project report, which will also contain the report of the Payload Panel. We expect this to be completed by late January. Readers may order the full report by writing to Charlotte Griner, Code 900, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, (CGRINER on GSFCMAIL), or by calling Linda Carter at (301) 513-1613.*

Atmospheres

This report summarizes the Atmospheres Panel Report to the EOS Payload Panel. The Report has five main authors: Mark Schoeberl (Panel Chairman), Jim Pfaendtner, Richard Rood, Anne Thompson, and Bruce Wielicki, with contributions from other members of the Atmospheres Panel.

In addition to a preface, the report has five major sections: I. Summary of Panel Recommendations, II. Clouds, Radiation, and Precipitation, III. Tropospheric Chemistry, IV. Stratospheric Chemistry and Dynamics, and V. Four-Dimensional Data Assimilation.

Preface

EOS instruments matching the data requirements for a given science objective are divided into three categories: Primary, Ancillary, and Contributing. A Primary instrument is one directly relevant to the core science questions; a Contributing instrument is one whose measurement would add to the overall pool of information in a positive way, but loss of data from that instrument would not cripple the science objectives as would loss of data from a Primary instrument; and an Ancillary instrument occupies the gray area in between.

With the proposed reduction of the number of instruments on a given EOS platform, more of the measurements will have to be brought together through the data assimilation process. Thus, in a sense, 4-D data assimilation becomes another "instrument" which provides key information in the form of meteorological and chemical data not directly measured.

I. Summary of Panel Recommendations

Only the major recommendations from the full panel report are given below. Some additional recommendations may be found in the full panel report, which is being published along with other panel reports by the EOS Project Science Office.

Clouds and Radiation

1. High priority should be given to an Earth Radiation/Cloud instrument package which includes CERES, AIRS+*, MIMR, MISR/EOSP, and MODIS-N. In addition, an inclined orbiting SAGE III (and/or polar orbiting HIRDLS) is needed for cloud, aerosol, and upper tropospheric water vapor and ozone studies.

2. MODIS-N cannot be replaced by AVHRR as the cloud imager on the afternoon orbit satellite. AVHRR is critically deficient for calibration, cloud particle size, cirrus cloud altitude, multi-level cloud systems, and boundary layer clouds. The critical synergism is CERES/MODIS-N/MIMR/AIRS+ and must be provided on at least one of the three spacecraft providing diurnal sampling.

3. The accuracy of monthly averaged radiation budget quantities will be significantly improved if CERES is on the NASA a.m. orbiting satellite with MODIS-N as opposed to the ESA platform with AVHRR + HIRS. For the second series of satellites, CERES + MODIS-N + MIMR is desired for all three spacecraft.

4. An early flight of MIMR would allow an overlap of at least one year with the TRMM rain radar for calibration of rainfall measurements.

5. Either GLRS or LAWS is highly desirable for measurements of polar cloud amount/height, planetary boundary layer height, three-dimensional cloud structure, and aerosol profiles. They will probably provide the only accurate cloud height information for polar region process studies.

6. MODIS-T cannot provide sufficient samples of cloud anisotropy in place of MISR.

Tropospheric Chemistry

1. MOPITT and TES should be flown as soon as possible along with instruments which measure surface processes and ocean color (e.g. MODIS-N). The measurements made by these instruments are high priority.

* AIRS+ is shorthand for the set AIRS/AMSU-A/MHS.

Stratospheric Chemistry

1. Two SAGE III instruments should be flown as soon as possible: one instrument for long-term ozone monitoring in a medium-inclination orbit, and a second for polar PSC and ozone measurements in polar orbit.

2. HIRDLS should be flown as soon as possible to provide continued global daily monitoring of the major trace gases in the stratosphere: O_3, H_2O, CH_4, N_2O, NO_2, $ClONO_3$, HNO_3, CFCs, and to provide high vertical and horizontal resolution temperature measurements throughout the stratosphere. (No temperature measurements will be available for the upper stratosphere after the UARS and the last SSU are flown.)

3. No decisions should be made concerning the EOS-B stratospheric instruments (MLS, SAFIRE, SWIRLS) until one year after UARS has flown. This would allow instrument investigators for SAFIRE, MLS, and SWIRLS to refocus their instruments on key problems identified by UARS measurements and key molecules identified by the Panel for monitoring. The Panel notes that while the combination of SAGE III and HIRDLS provides a significant amount of stratospheric information, information on the chlorine radicals and reservoirs and on the hydroxyl radical is lacking. The Panel views these measurements as *essential* to the success of any strategy focusing on global change. Furthermore, this data void will not be filled by foreign instruments.

Data Assimilation

1. AIRS+ should fly on the first platform since it provides the most direct path to addressing the validation issues for GCM parameterizations which led to the highest priority IPCC and CEES questions.

2. Accurate assimilated winds greatly enhance our ability to understand the hydrologic cycle. Thus, the Panel sees LAWS as a critical component of

EOS. Without atmospheric moisture transport and convergence estimates which "explain" observed regional precipitation patterns in the current climate, we will be unable to estimate the accuracy of GCM-simulated changes in the hydrologic cycle.

3. Scatterometer data from ERS-1 should undergo detailed evaluation in terms of data-assimilation-derived surface stresses before any nonreversible decisions are made regarding STIKSCAT.

II. Clouds, Radiation, and Precipitation

Four questions concerning the measurement of clouds, radiation, and precipitation are called out:

1. Can we accurately observe and predict the effect of cloud physical properties on the radiative energy fluxes at the surface of the Earth, within the atmosphere, and at the top of the atmosphere?

2. Can we accurately observe and predict cloud formation and dissipation given atmospheric state variables including: temperature, water vapor, wind (especially vertical velocity and shear), and aerosol amount?

3. Can we accurately observe and predict the amount of precipitation given atmospheric state variables and aerosol amount? Can we use precipitation as a tracer of latent heat release in the atmosphere?

4. Can we accurately observe and predict the effect of natural and anthropogenic aerosols on the radiative energy fluxes, both directly and through their effect on cloud microphysics?

Desired time and space scales for EOS global satellite *monitoring* observations are monthly average values within approximately 100-km-square regions. The primary variables to be measured for studies of clouds, radiation, and precipitation are: a) radiative fluxes at the surface, within the atmosphere, and at the top of the atmosphere for both shortwave and longwave radiation; b) numerous cloud and cloud particle properties; c) precipitation; d) atmospheric state variables including profiles of temperature, water vapor, and winds; e) tropospheric and stratospheric aerosol properties; and f) greenhouse gases including H_2O, CO_2, O_3, CH_4, and CFCs.

In general, *process* studies require observations with high spatial and temporal resolution. The "EOS-A" instruments will provide the highest spatial resolution observations, and geostationary satellites will be relied on for the high temporal resolutions that are needed to test cloud-scale and regional-scale models.

The full panel report identifies the sources of the major data sets for clouds, radiation, and precipitation. Time-sampling requirements and synergisms of multiple instruments are given as they relate to each of the four science questions. At one extreme there is a requirement for "near simultaneity" on the order of two minutes. This is for space and time variation studies of cloud optical depth, and the instruments in question are MODIS-N, CERES, and MIMR for cloud/radiation observations and MISR and MODIS-N for cloud anisotropy and aerosol observations. Other simultaneity requirements shown are on the order of 5 to 10 minutes. There is a requirement for an orbiting rain radar to overlap for at least one year with the MIMR passive microwave instrument.

In order to answer the science questions, the instruments listed in Table 1.1 are required. Table 1.2 summarizes the capabilities of the instruments for each science question.

III. Tropospheric Chemistry

In this section, once again, four science questions are posed and explained:

1. Trace Gases and Climate—Global Warming

   What is the source distribution of radiatively active gases with natural and anthropogenic origins: CH_4, N_2O, and CO_2? What is the natural and anthropogenically induced variability in ecosystems due to potential changes in temperature, acid deposition, rainfall, and UV radiation?

2. Tropospheric Ozone and Global Pollution

   What is the natural variability in tropospheric ozone? What are the magnitudes of ozone production from industrial activity and biomass burning?

Instrument Needs for Clouds, Radiation, and Precipitation

Science Question/ Core Instruments	Ancillary	Contributing
1. Clouds and Radiation CERES*, MODIS-N, MIMR, SAGE III, AIRS+, MISR, HIRDLS	LAWS≥GLRS	HIRIS≥ASTER
2. Cloud Formation MODIS-N, MIMR, AIRS+, 4D Assim	LAWS,SAGEIII LAWS≥GLRS	
3. Precipitation MIMR, Rain Radar, AIRS+, 4-D Assim	LAWS, MODIS-N	LIS
4. Aerosols and Radiation MISR/EOSP, SAGEIII*, CERES	GLRS, MODIS-N	HIRDLS

Notes:

≥ This symbol is used to indicate a preference for the first-named instrument
AIRS+ is a set of sounding instruments including AIRS, AMSU, and MHS.
CERES* is two scanning instruments on the same spacecraft, one sampling space, one sampling viewing angle.
4-D Assim is the use of a dynamical forecast model to improve the self-consistency of atmospheric profiles of temperature and wind, as well as to interpolate in time between observations.

Table 1.1

[It is pointed out that the "the single most important global change question in the troposphere is 'is tropospheric O_3 increasing?' "]

3. The Oxidizing Capacity of the Atmosphere

What are the spatial distributions of OH and H_2O_2 in the troposphere? What is the total OH abundance and will it change over the EOS observing period?

4. Trace Gases Containing C, S, and N

What are natural and anthropogenic sources of these gases?

Measurements are needed from space of tropospheric trace gases which have an *intermediate* lifetime (days to months). Concentrations of *shortlived* trace gases are inferred from UV flux and measurements of the intermediate lifetime gases, along with appropriate models and data assimilation.

The EOS instruments especially important are TES and MOPITT. In addition, the AIRS/AMSU-A/ MHS group is needed for oxidizing-capacity studies, and a MODIS-like imager is needed for determination of sources of reactive gases (see Table 2).

IV. Stratospheric Chemistry and Dynamics

The primary science question associated with stratospheric chemistry is "do we understand the evolution of stratospheric trace gas composition during a period of large anthropogenically forced changes in the stratosphere?" Subsidiary questions to this have to do with: understanding and prediction of global ozone changes; the role of polar ozone depletions in the overall ozone budget; the impact of unprecedented chlorine levels in the upper stratosphere; the impact of aerosols and NO_x from aircraft exhaust on the chemistry of the lower stratosphere; and the impact of the greenhouse gases (mainly CO_2) and water source gases (CH_4) on the chemistry and dynamics of the stratosphere.

The minimum requirement for global monitoring is a chemical cycles set and a basic physical environment measurement set. The minimum chemical set is determined by a radical and a reservoir from each of the major chemical families (O_x, NO_x, ClO_x, and HO_x) and the source gases for these families, e.g., N_2O for the NO_x family. The basic physical environmental set includes temperature, UV flux, winds, and aerosol/ cloud amounts.

Continuous global measurements are needed for temperatures, winds, aerosols/clouds, long-lived trace gases, some radical and most reservoir species. High-spatial-resolution measurements (about 2.5 degree longitude, 1 degree latitude, 3 km altitude) are needed for temperatures and long-lived trace gases to characterize the dynamics of the stratosphere though 4-D data assimilation. In the tropics, direct wind measurements are needed.

In addition to the instruments cited in Section I, the Panel noted the need for either SAFIRE or MLS to measure certain radicals (OH and ClO) and reservoirs (HCl and HF), for SWIRLS to measure stratospheric winds, and for SOLSTICE II to measure UV flux. The Panel stated that information on the chlorine radicals and reservoirs and on the hydroxyl radical is *essential* to the success of any

Capabilities of the instruments for Clouds, Radiation, and Precipitation Questions

1. Clouds and Radiation	
CERES*	Broadband radiation
MODIS-N	Cloud physical properties (amount, height, optical depth, particle size, and phase)
MIMR	Cloud liquid water path and cloud thickness (with MODIS-N)
AIRS+	Temperature and water vapor profiles, spectral surface and cloud emittance
MISR	3-D cloud structure and anisotropy, stereo cloud heights, impact on radiation budget
SAGE III	Upper tropospheric/lower stratospheric water vapor and ozone profiles (greenhouse gases)
HIRDLS	Upper tropospheric/lower stratospheric ozone and water vapor (greenhouse gases)
LAWS≥GLRS	Improved cloud heights: polar and multi-level clouds
HIRIS≥ASTER	Improved small-scale cloud properties
2. Cloud Formation	
MODIS-N	Cloud physical properties (as in [1] above).
MIMR	Cloud liquid water path and cloud thickness (with MODIS-N)
AIRS+	Temperature and water vapor profiles, spectral surface and cloud emittance
4-D Assim	Improved water vapor and wind profiles (including vertical velocity)
LAWS	Improve the accuracy of all 4-D assimilation products over ocean and in the Southern Hemisphere
SAGE III	Most accurate upper troposphere water vapor
LAWS≥GLRS	Improved cloud heights: polar and multi-level clouds, planetary boundary layer heights
3. Precipitation	
MIMR	Precipitation measurements over ocean, less accurate over land
Rain Radar	Calibrated rain radar, together with MIMR, provides precip over land and ocean
AIRS+	Temperature and water vapor profiles, spectral surface and cloud emittance
4-D Assim	Improved water vapor and wind profiles (including vertical velocity)
LAWS	Improves the accuracy of all 4-D assimilation products over ocean and in the Southern Hemisphere
MODIS-N	Precipitation estimates using thermal thresholds which may improve accuracy for convection over land
LIS	Lightning measurement to potentially improve precipitation measurements over land
4. Aerosols and Radiation	
MISR	Estimates of tropospheric aerosol properties using multi-wavelength multi-angle views.
EOSP	Estimates of tropospheric aerosol properties using multi-wavelength polarization
SAGE III	Stratospheric and upper tropospheric aerosol profiles
CERES	Broadband radiative effects of aerosols
MODIS-N	Estimates of tropospheric aerosol properties using multi-wavelength, multiple time views
GLRS	Improved vertical structure of tropospheric aerosols, but uncertain properties (size, single scatter albedo)

Table 1.2

Instrument Needs for Tropospheric Chemistry

Science Question/ Core Instruments	Ancillary	Contributing
Changes in Greenhouse Gases TES, MOPITT		
Tropospheric Ozone & Precursors TES, MOPITT	SAGE III, HIRDLS	LIS
Oxidizing Capacity TES, AIRS+, MOPITT	HIRDLS, SAGE III SOLSTICE	
Sources of Reactive Gases TES, MODIS-like Imager 4-D Assim	AIRS+, MIMR (rain) MISR, EOSP, Scatterometer	

Table 2

The initial data-assimilation work will focus on atmospheric applications and, in particular, on global transport characteristics and interseasonal and interannual variability. Future research will contain multiple foci on improved representation of hydrological processes, oceans, and surface processes. Data sets are to be produced in a timely fashion so that they may be used in conjunction with the many surface-based campaigns of the next five-to-ten years.

strategy focusing on global change. The Panel noted the instruments proposed by ESA for POEM-1 and by Germany for ATMOS, and concluded that none of these would relieve the burden on the U.S. of supplying its recommended sensors as part of the EOS payloads (see Table 3).

V. Four-Dimensional Data Assimilation

Data assimilation can provide the following capabilities: a) data-constrained studies of cloud, precipitation, and radiative processes; b) improved representations of climate in poorly observed areas; c) generation of best estimates of unobserved quantities of geophysical interest; d) improvement of data retrieval algorithms by supplying accurate first-guess fields; e) possible identification of sensitive parameters of climate change; and f) quality control of data. Two major Earth science questions to be addressed with assimilated data sets are these:

1. How well do the assimilated data sets represent the global transport of heat, energy, and constituents?

2. What are the sources and mechanisms of interseasonal and interannual variability?

Instrument Needs for Stratospheric Chemistry and Dynamics

Science Question/ Core Instruments	Ancillary	Contributing
Long-Term O_3 Trend SAGE III (1)	HIRDLS, MLS, SAFIRE	
Global Mapping O_3 HIRDLS≥MLS, SAFIRE (2)	TES (7)	AIRS/AMSU
Global Mapping H_2O HIRDLS≥MLS, SAFIRE (2)		
Global Mapping T HIRDLS≥MLS, SAFIRE (2) AIRS+		GGI, SAGE III
Radicals OH SAFIRE, (MLS) (3) ClO, (BrO) MLS NO_2 HIRDLS, SAFIRE, MLS	OClO (4) SAGE III NO_3 (4) SAGE III	
Reservoirs HCl MLS, SAFIRE HF SAFIRE, (MLS) (3)	$ClONO_2$ (5) HIRDLS HNO_3 (5) HIRDLS, SAFIRE, MLS	
Source Gases N_2O HIRDLS, SWIRLS CH_4 HIRDLS, SAFIRE Winds SWIRLS UV Flux SOLSTICE II Aerosols/PSC's SAGE III (6)	CFC's (6) HIRDLS HIRDLS	

Notes:

1. SAGE III in high inclination orbit similar to SAGE II.
2. HIRDLS is a limb instrument like MLS and SAFIRE but scans horizontally, thus making higher spatial resolution measurements than SAFIRE or MLS. As a result HIRDLS is preferred for these measurements.
3. The MLS PI (Dr. J. Waters) believes that the instrument will be able to make OH and HF measurements although the current proposed design does not include those measurements.
4. Very useful radical.
5. Very useful reservoir species.
6. Polar PSC measurements require SAGE III in polar orbit.
7. TES will provide important information on many stratospheric species, but its coverage only includes the lower stratosphere. Thus, in this regard, it is categorized as ancillary.

Table 3

The Panel's need for data for assimilation purposes includes the need for a rain radar as part of a hydrologic cycle package. LAWS will be a critical component. The AIRS/AMSU/MHS package should fly on the first of the EOS platforms "because it provides the most direct path to addressing the validation issues for general circulation model (GCM) parameterizations, which led to the highest priority IPCC and CEES questions" (see Table 4). ❑

Instrument Needs for 4-D Data Assimilation

Science Need/ Core Instruments	Ancillary	Contributing
1. Atmospheric Temperature and Winds AIRS+, LAWS, HIRDLS, SWIRLS	Scatterometer CERES, SAGE III	MODIS-N, MISR/EOSP
2. Hydrologic Cycle AIRS+, LAWS, Scatterometer Rain Radar	MIMR	MODIS-N, CERES, MISR/EOSP
3. Atmospheric Chemistry SAGE III, HIRDLS, TES, MLS, SAFIRE, MOPITT	SWIRLS, LAWS AIRS+	
4. Oceans and Surface Fluxes Scatterometer, LAWS, AIRS+	MODIS-N	CERES

Table 4

Land Biosphere/Biogeochemical Cycles

Introduction

Piers Sellers, Chair, Land Biosphere Panel
David Schimel, Chair, Biogeochemical Cycles Panel

The full report consists of six sections giving an introduction, a science framework, a statement of revised requirements for EOS, a proposed strategy for EOS (first series), land remote-sensing issues, arguments for early launch of the surface-imaging platform, and summary and recommendations. The summary presented here follows the outline of the report.

The report focuses on the issues associated with the first series of EOS platforms (those that can be expected to be launched in the period roughly 1997 to 2001). It is assumed that EOS will be rescoped into a more-flexible program, based on a series of small-to-medium-sized platforms.

I. Science Framework

This section contains reviews of land biosphere (LB) and biogeochemical cycle (BGC) panel science issues, the IPCC priorities in an LB/BGC context, and the main LB/BGC science priorities.

LB/BGC Science Issues

- *Biophysics*—the concern is to understand the controlling processes in order to better define the future patterns of carbon-energy-water exchange between the atmosphere and the terrestrial biosphere over the next 10-100 years.
- *Biogeochemical cycles* and *trace gas exchange*—the concern is to understand the changes in surface and atmospheric state variables over land and oceans that govern element cycling (especially of C, N, S, and P) within, and between, the land and ocean biosphere and the atmosphere.
- *Ecosystem dynamics* and *land-cover change*—the concern is to understand the current and future patterns of change in terrestrial and aquatic ecosystems in response to climate change and human activity and the feedbacks from changes to the hydrology/climate system.

Major Uncertainties

- How will the biophysical controls on the carbon, energy, and water cycles on the land surface respond, and feedback to climate change?
- How will the respiration component of the carbon cycle, particularly decomposition, change with climate change?
- How will ecosystems change in response to climate change and anthropogenic pressure, particularly with regard to feedbacks onto the climate system and with respect to the cycling and storage of carbon and trace constituents?

Possible Contributions of Remote Sensing

- *Biophysical controls*—corrected vegetation-index data from MODIS-N would be used to define the sink strengths for CO_2 and the source strengths for transpired water over the continents. In terms of estimating the surface fluxes of heat and water, improved vegetation-index data would be the land-surface equivalent of sea-surface temperature (SST) fields when applied as boundary conditions in climate models.
- *Estimating decomposition rates*—there would be a remote-sensing strategy in which HIRIS and MODIS-N, supplemented by 4-D assimilation, would be the key players. The role of HIRIS would be to supply measures of leaf organic chemistry, litter utilization rate, and microbial substrate utilization. MODIS-N would supply measurements of annual litter input.
- *Changes in ecosystems and biogeochemical cycles*—the report indicates roles to be played by a "surface-imaging package," which should include MODIS-N, MISR, TM and/or ASTER. There is also a need for an ocean circulation and ocean biogeochemistry package made up of an altimeter, a scatterometer, and an ocean color sensor using spectrometry. It is proposed that a MODIS-T class instrument should be in place by around the year 2000 to serve the needs of the ocean biogeochemistry community.

II. Revised Requirements for EOS

In a general discussion of revised requirements, it is pointed out that a measurement system is required that will provide adequate data for the study of critical issues within the science areas of the physical climate system, the carbon cycle, and aspects of biogeochemical cycles and ecology. The report calls for global-scale, multi-temporal measurements, subseasonal to decadal, of terrestrial vegetation dynamics. To improve capabilities significantly there is a need for sampling with high-spatial-resolution observations of ecosystem extent and character to better understand land-cover changes and community-scale changes associated with anthropogenic change, climate-forced succession, or disturbance. Lastly, measurements of tropospheric trace gas concentrations are needed.

The measurement needs can be broken out in terms of the three science areas defined as the *physical climate system*, the *carbon cycle*, and *biogeochemistry and ecology*. For the *physical climate system* it is necessary to resolve the diurnal cycle and to do this, four measurement sets of the atmospheric state variables are required per day. These can be provided by two sounder/imager polar platforms spaced a few hours apart. The proposed EOS measurements meet this requirement, as supported by ESA's POEM-1 platform in the a.m.

For the *carbon cycle*, measurements are needed for the atmosphere, the oceans, and the land. For the atmosphere, time-series measurements of carbon compound concentrations are required: CO_2, CH_4, CO, etc. Over the oceans, ocean color data are needed, which can then be combined with the temperature and shear-stress measurements to estimate carbon flux components. Over the land, a range of parameters associated with vegetation activity needs to be measured. For the land it is impossible to model the carbon cycle realistically without accounting for energy and water transfer; thus the requirements for land carbon-cycle studies almost completely overlap those for the physical climate system studies.

For *biogeochemical cycles and ecology*, measurements are again needed for the atmosphere, the oceans, and the land. For the atmosphere, the objective is to monitor and understand greenhouse gas concentrations and chemistry. Over the land and oceans, the objective is to specify the source and sink strengths for the major greenhouse gases, the controlling state variables and, in the case of the land, the links to ecosystem status. Also, over the land it will be necessary to observe land-cover change, and the dynamics and extent of disturbances at high spatial resolution.

III. A Proposed Strategy for EOS (First Series)

The gist of the proposed strategy is summarized in Section 6, which is presented near-verbatim at the end of this writeup.

IV. Land Remote-Sensing Issues

This section discusses overpass time and orbit, multi-angle remote sensing for land-surface studies, and high-spatial-resolution remote sensing, and gives the Panel's position on HIRIS and SAR. A mid-morning crossing time in a descending orbit is desired, and 10:30 appears to be optimum for cloud avoidance while still achieving adequate illumination in the northern hemisphere. This crossing time would also lead to the possibility of simultaneous or near-simultaneous data acquisition with Landsat TM.

MISR is preferred over MODIS-T for multi-angle remote sensing for regional-to-global-scale studies of the land surface. MISR offers continuous global coverage and quasi-operational calculation of albedos, aerosols, correction of MODIS-N data, and surface anisotropy products.

For high-spatial-resolution remote sensing, TM is preferred over ASTER because of the proven record and continuity of TM in contrast to the "hope" for a successful resolution of the uncertainties associated with ASTER.

There is some uncertainty as to whether HIRIS can provide the desired information on canopy chemistry, but the information would be of great value, and accelerated research into potential HIRIS capabilities is needed. There should be a study report at the end of three years. For SAR, the community needs to set up a mechanism to carefully compare the proposed SAR capabilities with the, as yet, unclearly stated requirements. SAR data on biophysical and structural parameters under all weather conditions could prove invaluable.

V. Early Launch of the Surface-Imaging Platform

There are both scientific and social viewpoints that argue for an early launch of the 10:30 surface-imaging platform. Scenarios for greenhouse-gas-induced climate change indicate that there may be detectable changes in land-surface processes early in the projected climate transition. From a social viewpoint the land is where people live and where they will be most affected by changes that cause losses in food production or water resources.

The principal means of accomplishing global remote sensing at present are AVHRR, Landsat, and SPOT. In general, there is a calculable limit as to what can be done with the ensemble of AVHRR, Landsat, and SPOT. These systems give a qualitative description of some of the phenomena important to LB/BGC issues, but not a quantitative resolution of the issues.

Relative to the atmospheres and oceans, remote sensing of the land surface is in bad shape, and so this is another reason to have an early launch of a surface-imaging platform.

VI. Summary and Recommendations

(Material presented here is quoted near-verbatim from the full LB/BGC panel report to the EOS Payload Panel.)

The LB/BGC panel recommends that:

(i) A surface-imaging package be assembled for early launch. It should have a descending orbit with a 10:30 equator crossing time. The package should include: MODIS-N, MISR, TM, and/or ASTER.

Landsat-TM should be flown in formation with the platform if ASTER is already in place.

(ii) A sounder-imager package should be assembled for the second launch. It should have an ascending orbit with a 13:30 equator crossing time. The package should include: MODIS-N, AIRS/AMSU/MHS, CERES, and MIMR.

(iii) The needs of the ocean circulation and ocean biogeochemistry community must be met if Earth Science in general and the LB/BGC community in particular are to succeed. The needs are: Altimeter, Scatterometer, and ocean color (spectrometry). A continuous program of ocean scatterometry measurements must be maintained; this will require collaboration with international partners. A MODIS-T class instrument should be in place by around the year 2000 to serve the needs of the ocean biogeochemistry community. ❑

Oceans

Mark R. Abbott, Chair
Michael H. Freilich

Introduction

It has long been recognized that the oceans play a crucial role in the climate system. Oceans cover more than 70% of the Earth's surface. As noted in the Intergovernmental Panel on Climate Change (IPCC) report (*Climate Change, the IPCC Scientific Assessment, 1990*), more than 50% of the solar radiation reaching the surface is absorbed by the oceans; this energy is redistributed through advection by ocean currents and released back to the atmosphere through evaporative and long-wave radiation processes. On average, ocean currents account for ≈75% of the total meridional heat flux at 20° latitude and ≈40% of the total at 40° (with the atmosphere contributing the rest; cf. Trenberth, 1979). It is estimated that 86% of all global evaporation and 78% of all precipitation takes place over oceans (WCRP/GEWEX, 1988; Baumgartner and Reichel, 1975). The advective and evaporative/precipitative processes are determined largely by ocean currents driven by momentum input to the oceans by surface winds; these currents, along with variations in the vertical attenuation of solar radiation (largely driven by changes in bio-optical properties), in turn help establish the sea-surface temperature patterns which strongly modulate evaporation and atmospheric surface layer phenomena.

The oceans also serve as huge reservoirs of elements and chemical species to which the climate system is sensitive. For example, the 600 gigatons of carbon present in the oceanic Dissolved Organic Matter (DOM) pool is as large as the total vegetative carbon reservoir on land. The oceanic DOM has a biogenic origin, although details of the DOM cycle are not well known. What *is* clear is that DOM formation and destruction is species dependent, and thus environmental oceanic processes that modify the composition of species assemblages will change the quantity of oceanic DOM. Further, transfer of carbon and a host of other chemical species across the air-sea interface is tightly controlled by ocean surface and atmospheric surface layer phenomena, key among which are winds. The incorporation of inorganic carbon by marine plants and its role in carbon cycling in the ocean is not well-understood on mesoscales and seasonal time scales. For example, it has been hypothesized that significant downward flux of organic material occurs on mesoscales, and that this is strongly modulated by seasonal forcing. More importantly, it is not known how these biogeochemical cycles will respond to changes in physical forcing that may result from climate change.

Owing to the ocean's large spatial extent and crucial role in the Earth's climate system, accurate, extensive measurements of many upper ocean and atmospheric surface layer quantities must be acquired; without these measurements, the EOS program will not achieve its global-scale scientific and policy goals and objectives.

Specifically, data are required to understand and monitor the physics of the upper ocean (currents, temperatures/heat content, surface geometry); the biological processes that occur in the upper ocean that influence the chemical form of climate-sensitive species; and the air-sea interaction processes that, through ocean-atmosphere fluxes, couple the Earth's two great fluid systems. Over the past decades, techniques to acquire these measurements from satellites have been developed, refined, and tested. These techniques include multi-spectral measurements of ocean color; scatterometer measurements of all-weather surface vector winds; altimeter measurements of surface slope (and hence geostrophic currents); multi-channel microwave radiometer measurements allowing estimation of all-weather sea-surface temperature, wind speed, atmospheric water content, and a host of other quantities; SAR measurements of ice motion and associated liquid and solid water properties; and high-resolution infrared measurements of sea-surface temperature.

The requirements for these observations, the scientific rationale, and the proposed measurement plans have been described in a long series of NASA and National Academy of Sciences reports. Rather than repeat the conclusions of these reports, the Oceans Panel emphasizes that there have been no fundamental changes in the requirements related to the observation of ocean processes. The challenge for the EOS era is to continue the measurement programs begun in the 1990s with TOPEX/POSEIDON, NSCAT, SeaWiFS, SSM/I, and ERS-1 with a view towards collecting a sufficiently long-time series to study critical low-frequency variability as well as provide overlapping observations of a variety of physical and biological processes in the ocean. The primary focus of the EOS era will be the development of a comprehensive suite of ocean and atmosphere data sets with which to study coupled ocean/atmosphere processes, including the linkages between physical and biological variables.

Recommendations

Notwithstanding the central role of the oceans in the substance of EOS science and policy issues, the Oceans Panel is faced with a unique and undesirable situation; namely, MODIS-N is the only NASA-supplied instrument with applicability to addressing ocean measurement needs, and MODIS-N and MIMR are the only ocean-related instruments tentatively manifested on the NASA EOS platforms (based on the Seattle meeting). The panel thus concludes first that: *The NASA-provided and/or-flown instruments in the "Seattle" payload do not supply even the minimal suite of ocean-related data needed to make substantive progress toward the stated goals of the EOS program.*

With these constraints in mind, the Oceans Panel developed a strategy based on the following principles. First, the panel assumed that there would be considerable progress in the next ten years as the result of both satellite missions (such as TOPEX/POSEIDON, ADEOS/NSCAT, and SeaStar/SeaWiFS) and global-scale field campaigns (WOCE/TOGA and JGOFS). These studies should significantly advance our understanding of ocean processes, and future satellite missions should concentrate on the linkages between physical, biological, and chemical processes and their role in the ocean/atmosphere system. Second, an attempt was made to balance the need for continuity of ocean data sets versus the need for an improved data set (along with a possible gap in the time series). This was based on an assessment of the scientific value of particular measurement capabilities along with the associated risk. Risk was broken into two components: *technical risk*, which is a measure of the ability to obtain data sets of sufficient quality to meet the scientific objectives, and *programmatic risk*, which is a measure of the commitment to obtain the data sets.

The Oceans Panel recommendations thus address questions related to "where will required data come from during the EOS era?" The panel recognizes that the production of "required data" for EOS scientists entails both capable instrument designs and the programmatic commitment (on the part of non-EOS entities either within or external to NASA) to actually carry the instruments through to flight. It is also essential that attention be paid to the complete data processing and delivery system and any associated data policies. Reliance on inaccurate measurements, or those having insufficient coverage or resolution, will doom the subsequent analysis. Similarly, reliance on partners to supply crucial data is irresponsible in the absence of a thorough evaluation of the capability and commitment of the partner to carry the project through to completion. While risks cannot be eliminated, all relevant aspects of risk must be evaluated before transferring responsibility for crucial data sets to others.

While reliance on partners is beneficial and necessary, *EOS must institute procedures to obtain and monitor information related to the programmatic status of critical partner instruments; whenever possible, EOS must apply relevant pressure on partners to commit to the early flights of instruments having the required accuracy, coverage, and resolution. Without such information and leverage, the NASA EOS program cannot make responsible tradeoffs between crucial (but potential) partner-supplied data sets and scarce EOS resources.*

In priority order, the Oceans Panel thus makes the following recommendations in the areas of ocean color, scatterometry, altimetry, microwave radiometry, SAR ice measurements, and infrared high-resolution SST. *We note that the first three issues (ocean color, scatterometry, and altimetry) are deemed of equal critical importance when evaluated in light of the scientific, technical, and programmatic risks associated with the full suite of measurements / instruments.*

Ocean Color

- *Data from MODIS-N and a MODIS-T-class ocean color sensor are required early in the EOS era. This includes full global coverage at high spectral resolution to study processes related to the ocean carbon cycle. In order to minimize risk, the following steps must be taken:*

1. EOS should work closely with JGOFS to develop and validate globally based algorithms that derive bio-optical properties and primary productivity from ocean color sensors;

2. EOS should strongly support immediate activities within NASA to obtain ocean color data of at least SeaWiFs-class after the initial flight of SeaWiFS, with the aim of eliminating any gap between the follow-on data and the initial SeaWiFs data set;

3. EOS should develop a program to launch an ocean color spectrometer of MODIS-T performance capability in the early part of the next decade to collect critical, global information on dissolved and particulate materials in the upper ocean in order to determine the roles that various phytoplankton groups play in carbon fixation and cycling.

After evaluating the plans of ESA and NASDA partners to fly the ocean color instruments, MERIS and GLI, it is noted that if flown on platforms with the present orbital parameters for POEM-1 and JPOP-1, there will be insufficient sun levels and excessive glint in the critical southern ocean region, thus severely degrading the utility of these data sets.

Wind Scatterometry

- *All-weather vector wind data having NSCAT-class coverage and accuracy are required through-*

out the EOS era. These data will be used to study the flux of momentum between the ocean and atmosphere as well as gas exchange.

1. As NASA and ESA are the only agencies with the capabilities and plans to fly scatterometers in the EOS era, EOS should conduct a program that will ensure flights of Ku-band scatterometers starting early in EOS, in the event that the planned ESA C-band scatterometer has insufficient coverage or accuracy, or does not fly owing to ESA programmatic decisions;

2. EOS should strongly support existing NASA and international plans to calibrate/validate the present ERS-1 scatterometer instrument and subsequently to investigate the utility of the C-band data for the solution of geophysical problems.

At present, engineering calibration difficulties are preventing analysis of the ERS-1 scatterometer data and refinement of the C-band model function. In addition, informal information obtained from ESA representatives indicates that the baseline scatterometer proposed for flight on POEM will be a single-sided instrument sharing time with the SAR, thus resulting in unacceptable coverage even if the instrument itself acquires accurate data. If ESA flies only a single-sided scatterometer instrument, NASA must also fly a scatterometer in order to achieve the required coverage.

Ocean Topography/Altimetry

• *Altimeter measurements with overall errors equal to or less than those provided by the TOPEX/POSEIDON mission are required throughout the EOS era. These data will be used to study the role of mesoscale and basin-scale circulation in global heat flux.*

1. NASA/EOS and its foreign partners should design at least one instrument/mission combination, to be flown continuously as necessary, to assure that TOPEX/POSEIDON-class data are obtained;

2. EOS should actively participate in the development with ESA of the ARISTOTELES gravity mission;

3. EOS should strongly support DoD efforts to fly GEOSAT follow-on missions during the EOS era, in order to provide better sampling (albeit at lower accuracy);

4. EOS should provide strong support for analysis of data from the ERS-1 altimeter, TOPEX/POSEIDON when it flies, and associated field studies such as WOCE.

At present, achievement of TOPEX-class error budgets requires the ability to determine the orbit precisely, and to correct for ionospheric refraction and path delays owing to atmospheric water. While these attributes may be most easily achieved by flying a two-frequency altimeter, nadir-looking microwave radiometer, and a precision tracking instrument on a free-flyer, the panel encourages continued study of alternative mission scenarios that would provide data with the required accuracy.

Microwave Radiometry

• *MIMR-class multichannel microwave radiometer data are required throughout the EOS era for the calculation of latent heat and moisture fluxes, all-weather sea surface temperature, atmospheric sounding in all-weather conditions, and sea ice monitoring.*

1. EOS should ensure that the initial flight of MIMR takes place as early in the program as possible;

2. EOS must continue to support and strengthen ties between NASA and DoD to allow EOS investigators access to the operational (but less capable relative to MIMR) SSM/I radiometer data collected by the DMSP program;

3. EOS must continue to support scientific investigations aimed at demonstrating the utility and capabilities of the SSM/I radiometers.

Infrared High Resolution Radiometry

• *High-quality, calibrated infrared SST measurements must be continued to monitor long-term global climate change and to serve as a parameter involved in global change processes, such as air/sea heat flux.*

1. EOS should ensure an early flight of MODIS-N to monitor SST;
2. EOS must continue to support and strengthen ties between NASA and NOAA to allow EOS investigators continued access to the operational (but less capable) infrared radiometers, such as AVHRR and VIRSR;
3. EOS should continue to support joint work with NOAA to make the 10-year time series of NOAA AVHRR data available to EOS researchers.

Infrared observations of the ocean's surface are often overlooked or only mentioned in passing when discussing priorities for the EOS period. This is because such observations are taken for granted. Given the danger of overlooking their continued (into the next century) acquisition or of allowing a deterioration of their quality when discussing which sensors are to be flown in the EOS timeframe, we feel that it is appropriate to reiterate the importance of continued satellite infrared observations of the ocean's surface.

Synthetic Aperture Radar

• *SAR data with sufficient coverage and frequent sampling are required to measure sea ice motion and determine surface forcing of the polar oceans.*

1. EOS must work in concert with partners to assure that wide-swath (>300 km), medium-resolution (~100 m) and narrow-swath, high-resolution SAR data are acquired in the polar regions throughout the EOS era;
2. For narrow swath SARs, EOS should ensure that proper orbits are selected for ice motion studies;
3. EOS should continue to support NASA-DoD ties for SSM/I correlative data as discussed under altimetry above;
4. EOS should continue to support joint work with Canada to ensure that pre-EOS RADARSAT data are processed fully and disseminated to EOS investigators.

Summary

The atmosphere and the ocean are the two great fluids of the Earth system. Changes in the coupling of these two fluids will have a profound impact on the Earth's climate and biogeochemical systems. Although changes in atmospheric composition and dynamics are the usual focus of global climate models, it is apparent that the ocean plays a critical role in modulating the magnitude and rate of these changes. The ocean is responsible for nearly half of the poleward heat flux as well as for a significant portion of the uptake of atmospheric carbon dioxide. However, the processes governing the flux of materials and energy between the ocean and the atmosphere are poorly understood. Such processes include not only physical and chemical dynamics, but also biological processes which act to modify the chemical composition of the ocean as well as the trapping of solar energy as heat in the upper water column. Thus it is essential that the ocean be studied as a complete system of physical, chemical, and biological processes. Overlapping measurements must be made for at least 10-15 years to resolve critical low-frequency fluctuations. The present EOS plan relies heavily on non-EOS entities to provide critical data sets for ocean studies. Although such partnerships are usually beneficial, there are risks that must be considered in terms of data coverage, quality, resolution, and availability. A simple replacement of an EOS sensor with a non-EOS sensor based on the fact that they both measure the same quantities will not guarantee that critical measurements will be made to address IPCC priorities in the area of ocean processes. EOS must continue to pursue appropriate methods to ensure that such partner-provided measurements meet scientific requirements. Such methods are analogous to contingencies applied in the area of schedules, cost, and performance for instrument projects. EOS must foster strong ties between U.S. scientists and their foreign counterparts, in order to develop partnerships based on science, rather than just based on financial or administrative considerations.

Effective international programs are necessary for a truly globally-based study, and they must begin with working scientists. In the area of ocean sciences, several opportunities exist in the early EOS era, such as ERS-1, TOPEX/POSEIDON, and NSCAT/OCTS/SeaWiFS. We strongly encourage EOS to contribute to these efforts. ❑

Modeling

Robert E. Dickinson, Chair

Framework

Modeling is an integral component of much of the EOS program. Indeed, all of the algorithms required to analyze the EOS data streams will be based in part on models of physical processes. This panel does not address the modeling issues related to algorithms needed to support individual instruments or synergistic analyses of data from multiple instruments. These are being treated by individual instrument and interdisciplinary teams. Rather, the Modeling Panel is concerned with those questions or modeling areas that cut across the interests of at least several of the interdisciplinary teams and form linkages to the rest of the international global change program.

With these concerns in mind, the overall objective of the Modeling Panel is to improve Earth system models as required to better understand and project global change and to synthesize and interpret EOS observations in this context. In general this can be done through:

- Better treatment of system submodels (individual processes).
- Data sets (regional or global) for indicating model performance.
- Data to initialize and be assimilated by global data sets as a byproduct.
- Data provided as boundary conditions to models.

Until more complete Earth system models are developed, the focus of the Modeling Panel will be on comprehensive climate models and carbon cycle models. Much of the present and future considerations of the Modeling Panel in this context are driven by whatever is the defined EOS suite of instruments, rather than providing a focus on the optimum mission at a given budget level. For example, how should global change systems models be best structured to use the EOS data? However, some important requirements for modeling are relevant to consider in defining the optimum mission for a given budget level.

Modeling Issues

1. Major Science Bottlenecks in Projecting Global Warming

- What will people do (largely excluded here)?
- Where does all the missing CO_2 go?
- For given greenhouse increases, how does the climate system respond — globally and regionally?
  - Oceans take up and redistribute heat, including sea ice changes.
  - Clouds change — affect global and regional energy balance: top of the atmosphere and at the surface.
  - Aerosols perturb radiation directly and through clouds.
  - Patterns and amounts of precipitation change.
  - Changing storage of water in land ice, changing ocean levels.
  - Water in soils and through vegetation interacts with atmospheric precipitation.
  - Atmospheric climate patterns shift — coupled to oceanic SST changes and changes in land energy fluxes.

2. Data Assimilation

Global analyses of meteorological data are carried out routinely by various institutions with operational missions. Data sets archived from these operations have, in turn, become a major source of information on atmospheric winds and temperatures as 3-dimensional time-varying fields. The usefulness of this process for analysis of long-term trends has been limited by changing model systems and analysis procedures. In principle, a homogeneous data set can be achieved by redoing the process (reanalysis) over a substantial time period using a single model and system.

Analysis of other global variables by the same assimilation systems is possible and desirable, but limited by the meaningfulness of the model treatment of the process that provides the other variables. For example, global humidity fields have been analyzed in routine assimilation procedures of varying weather services but not satisfactorily because of limitations in both the data and modeled atmospheric hydrological cycle.

Considerable effort is currently going into the improvement of model treatments of surface and planetary boundary layer processes. Consequently, observations of surface winds have become valuable, e.g., as measured over the oceans with scatterometers. Furthermore, with these winds, plus adequate values for other surface atmospheric fields, surface fluxes of energy and water should be obtainable, as well as soil moisture within the limitations of its model and precipitation inputs. Cloud properties and precipitation are also targeted for including in future data assimilation processes. New variational approaches apply to any such variable.

3. Global Data Sets for Model Testing and Boundary Conditions

At least some of the 3-dimensional fields important for climate models must be constructed independent of model assimilations, to avoid both unmanageable complexity and biases that would otherwise be imposed by the models. Such data analyses should be more useful for model validation than those based on the models. A general requirement of such analyses is that they provide at least the spatial resolution used by the models, which, in the EOS time-frame, will be an order of magnitude better than has been needed by global climate models (future resolution is anticipated to be about 50 km).

In developing data sets for testing models, it should be recognized that ability to simulate regional climates is a key requirement of the models that have been tested very little as yet, let alone validated. Furthermore, it is important to recognize important global integral quantities that must be accurately simulated.

Data Requirements

The four-dimensional assimilations as presently carried out require measurement of three-dimensional fields of temperature and winds; present accuracies meet requirements only over the more populated land areas of the Northern Hemisphere, if at all.

With current and future improvements, the assimilations will also need accurate moisture soundings and surface fields — winds, surface air and skin temperatures, moisture distributions, and wave properties over the oceans.

1. Global Data Sets for Model Testing and Boundary Conditions

- Stratosphere (refer to Atmospheres Panel).
- Troposphere: cloud/radiation and hydrological cycle; patterns of wind, temperature, and humidity leading to clouds and precipitation.
- Land:
  - Biophysical: seasonal and year-to-year variations in leaf cover properties, including density and spatial distributions, albedo, roughness, precipitation, net radiation, soil water content, and maximum water holding capacities.
  - Ecological/biochemical: in addition to above, canopy structure and biomass, concentrations of tropospheric trace gases coupled to land.
  - Geophysical: high-resolution local event processes coupled to global system e.g., volcanos.
- Oceans (refer to Ocean Panel for details):
  - Carbon cycle related.
  - Surface energy exchange and energy redistribution processes, including polar/ice.

Recommendations

- General: Appropriate balance — guided (but not too rigidly) by need to reduce the major uncertainties that will remain a decade from now in projecting greenhouse warming through models.
- Troposphere: ensure eventual adequate capability for global assimilation of fields of winds, temperature, and humidities; details as to how these form clouds; cloud properties and radiative fluxes; how is precipitation formed, and what are the amounts and distribution; aerosol radiative effects.
- Stratosphere: emphasize constituent, dynamical, and radiative coupling to troposphere. Keep present options open to do further measurements of stratosphere until adequacy of UARS is evaluated.

- Oceans: ensure presence of a scatterometer and sea ice property measurements.

- Land: ensure the adequacy of the meteorological and radiative models for providing surface energy exchanges (also applies to oceans above). Measure land properties for global data and process information. ❑

Physical Climate and Hydrology

Eric Barron, Chair

The material on priorities, which follows, was excerpted from a full-length report by the Physical Climate and Hydrology Science Panel of EOS to the Payload Advisory Panel. There have been some minor modifications to make this version of the report stand on its own. The full report is to appear in a special EOS volume mentioned on page 2.

Proposed Instrument Priorities

Much of the uncertainty in global change predictions involves climate and hydrology. The large number and nature of these uncertainties demands a comprehensive interdisciplinary foundation for EOS. The Panel report outlines the key measurements needed to tackle the issues and uncertainties, and describes contributions by EOS which would serve to fulfill the most important objectives of the physical climate and hydrology investigators. Each of these objectives is of substantial importance and prioritization is difficult. The Panel, although reluctant to yield on any of the major EOS objectives, has established priorities based on four criteria: (1) the importance of the scientific question, (2) the human, or policy, significance related to uncertainties in global change predictions, (3) the magnitude of the potential scientific advance by EOS, and (4) the potential for EOS to accomplish the objectives. The proposed instrument priorities follow from these criteria.

First-Order Priorities

Key Objective A-1: To determine how the global and regional storages and fluxes of water, including precipitation (snow cover, evaporation/transpiration, and runoff), are affected by the increasing concentrations of atmospheric trace gases.

Critical Science Issues: We lack fundamental knowledge on surface moisture fluxes and their long-term variability and, therefore, the response of the terrestrial hydrologic cycle to global change is highly uncertain. The spatial heterogeneity of soils, vegetation, snow cover, and precipitation and their inadequate treatment in predictive models is a key limitation in producing regional predictions of global change. Precipitation, water vapor structure, evaporation, transpiration, and snow cover have not been the focus of climate model verification and validation. Knowledge of the processes of land surface-atmosphere interactions and the boundary layer is critical to the extension of predictability from global to regional scales.

Policy Implications: Because of the enormous significance of water as a human resource, changes in local and regional water balance have critical and far-reaching societal impacts. These impacts include potential changes in water supply for domestic, agricultural, and industrial use, changes in storm tracks and intensity that could affect the frequency and magnitude of flooding, and potential changes in land-surface ecosystems. Global climate model experiments for increased concentrations of atmospheric carbon dioxide predict an increased tendency toward aridity and drought, particularly in the interiors of continents in mid-latitudes. Both the model predictions and the evidence of natural variability within the climate system suggest that changes in global and regional water balance will emerge as one of the most critical societal issues of the next decades because of the enormous significance of water as a human resource.

Potential for Scientific Advance: There have been few attempts to link physical climate and the terrestrial system to describe realistically the interactions between the surface and the atmosphere. Current knowledge of how energy and water fluxes are linked with surface characteristics is weak. Addressing the important issue of translating from global-scale predictions to regional scales depends on our ability to address the spatial and temporal heterogeneity of hydrologic and terrestrial variables.

Science Needs: The primary scientific requirements are to: (a) develop a representative precipitation climatology; (b) derive a global-scale assessment of evapotranspiration, based on indirect methods involving coeval measurement of vertical water vapor distribution, precipitation, winds, and temperature; (c) obtain surface radiation fluxes and compute the surface energy balance; (d) derive a global assessment of surface characteristics including vegetation types, soil moisture, soil type, texture, hydraulic properties, rooting depth, and field capacity; (e) derive the distribution, amount, and spatial and temporal variability of snow cover; and (f) determine a global quantification of run-off.

EOS Instruments: The following instruments will aid substantially in addressing these needs: AIRS/AMSU-A/MHS, ASTER, CERES, HIRIS, LAWS, LIS, MIMR, MISR, MODIS-N and EOS SAR.

Recommendations:

(1) ASTER (with HIRIS as a future platform candidate), MODIS-N, and MISR on a morning platform are essential.

(2) AIRS/AMSU-A/MHS, MIMR, and MODIS-N are an essential package. The addition of CERES greatly enhances surface radiation estimates.

(3) EOS SAR and LAWS are given high priorities in order to determine surface attributes by active methods and to derive moisture transports, respectively. LIS would be a complementary instrument for precipitation.

Key Objective A-2: To ascertain the factors which determine cloud properties and which govern cloud-radiation feedbacks, and hence the climate response to increased concentrations of greenhouse gases.

Critical Science Issues: Clouds are of first-order importance in determining the radiative properties of the atmosphere, and serve as locations for latent heat conversion. The effect of cloudiness depends on the vertical and horizontal extent and locations of clouds as well as micro- and macrophysical properties. The condensation, precipitation, and motion fields associated with clouds are an essential component of the hydrologic cycle. Clouds constitute one of the potentially most important feedback mechanisms in climate change.

Policy Implications: Cloud-climate feedbacks are one of the major uncertainties in the prediction of the magnitude of global warming due to the increased concentrations of atmospheric trace gases.

Potential for Scientific Advance: The highly variable nature of cloud properties in space and time, and the complexity of cloud characteristics have limited our ability to provide a representative climatology of all the variables needed to depict accurately the three-dimensional interaction of clouds within the Earth system despite a lengthy history of measurement. Increased quantitative measurements of cloud micro- and macroscale properties are essential if we are to understand the role of clouds in climate change.

Science Needs: Enhanced spatial and spectral resolution in the measurement of cloud properties is needed. Determination of optical depth and mean particle radii with simultaneous measurement of tropospheric aerosols, boundary-layer winds, water vapor abundance, and cloud properties is also needed. Better determinations of ice and liquid condensate at multiple levels are required.

EOS Instruments: The following instruments will aid substantially in addressing these needs: AIRS/AMSU-A/MHS, CERES, EOSP, LAWS, MIMR, MISR, MODIS-N, and STIKSCAT.

Recommendations:

(1) CERES, AIRS/AMSU-A/MHS, and MODIS are the most critical instruments.

(2) EOSP or MISR would provide enhanced information on tropospheric aerosols.

(3) LAWS and STIKSCAT should be flown. LIS could provide complementary information regarding convective clouds.

Key Objective A-3: To determine whether changes in ice sheet and glacier mass balance will result in a rise in sea level in the next century.

Critical Science Issues: Climate model studies of future global change suggest that snow cover, sea ice, and continental glaciers and ice caps will be highly sensitive to global warming. It is not known whether the volume of ice on Earth is decreasing or increasing. Knowledge of snow accumulation, transformation, and melting are inadequate.

Policy Implications: Changes in ice volume translate into major shifts in sea level and shoreline position, with major economic and legal ramifications.

Potential for Scientific Advance: Knowledge of the change in mass balance of the major ice sheets would be a first-order advance in a major scientific issue which is currently only the subject of speculation.

Science Needs: Measurements of thickening or thinning rates, particularly over the steeper parts of ice sheets, ice velocities, and snow accumulation rates are needed.

EOS Instruments: The following instruments will aid substantially in addressing these needs: GLRS-A and EOS SAR. Determination of surface energy and moisture budgets would enhance this objective: CERES, AIRS/AMSU-A/MHS, and MODIS-N.

Recommendations:

(1) GLRS-A is an essential instrument.

(2) EOS SAR should be a high priority; there may be budget problems.

(3) CERES, MODIS-N, and AIRS/AMSU-A/MHS may enhance water balance calculations.

Second-Order Priorities

Key Objective B-1: To determine the feedbacks and interactions between the atmosphere and land surface hydrology that will define the response to accelerated human-induced changes in land surface characteristics.

Critical Science Issues: The characteristics of the land surface, particularly soil and vegetation characteristics, have a profound impact on global and regional climate through controls on transpiration and evaporation. The interactions of the land surface and the atmosphere are incorporated only in a primitive fashion in global climate models through highly simplified boundary layer processes.

Policy Implications: The increased degradation of the landscape (for example through deforestation) resulting in increased surface albedo may promote drought. Accelerated changes in land surface characteristics including agricultural activities, urbanization, deforestation, and human-induced desertification are increasingly influencing climate and, in turn, are affected by changing climate.

Potential for Scientific Advance: There is insufficient knowledge of how energy and water fluxes are linked with the vegetation morphology and physiology. Much of the uncertainties reflect the lack of coeval measurements of soils, soil moisture, vegetation characteristics, snow cover, and the state of the overlying atmosphere.

Science Needs: The key measurement needs are to: (a) develop a synergistic knowledge of climate (vertical water vapor distribution, precipitation, winds, and temperature), soils, and the physiology and morphology of vegetation at regional and local scales; (b) determine the scale of the variability of surface characteristics; and (c) assess the temporal characteristics of land use and vegetation changes.

EOS Instruments: The instrument requirements are very similar to the needs described for objective (A-1), and include: AIRS/AMSU-A/MHS, ASTER, CERES, HIRIS, LAWS, MIMR, MISR, MODIS-N, and EOS SAR.

Recommendations:

(1) Congruent measurements by ASTER (with HIRIS as a future platform candidate), MODIS-N, AIRS/AMSU-A/MHS, MIMR and MISR are required. The addition of CERES enhances surface energy budget calculations.

(2) EOS SAR and LAWS are high priorities.

Key Objective B-2: To determine the factors governing the moisture and energy balance and its variability over the ocean, its influence on ocean circulation, and its role in climate variability.

Critical Science Issues: The feedbacks between the oceans and the atmosphere govern climate variability on decadal and longer time scales and the response of the climate system to different climatic forcing factors. Predictive models of the coupled ocean-atmosphere system are still rudimentary. Changes in climate and the hydrologic balance, particularly in high-latitude regions of deepwater formation, may contribute to rapid state changes in the ocean circulation.

Policy Implications: The nature of the feedbacks between the oceans and the atmosphere will likely govern the timing of global climate change and the nature of climate variability.

Potential for Scientific Advance: Evaporation over the oceans is a critical hydrologic quantity which is poorly known globally. Air-sea interaction is poorly understood. Knowledge of the relations between the variability of sea surface temperatures, sea ice, surface moisture fluxes (salinity), and the variability of the large-scale meridional circulation would substantially advance our understanding of climate variability and the potential for ocean-related abrupt changes in climate.

Science Needs: The key science needs are: (a) assessment of ocean evaporation based on knowledge of atmospheric relative humidity, atmospheric temperature, sea surface temperature, and wind stress; (b) ocean altimetry; (c) seasonal and interannual distribution of sea ice, (d) ocean precipitation; and (e) planetary boundary layer height.

EOS Instruments: The following instruments aid substantially in addressing these needs: AIRS/AMSU-A/MHS, CERES, LAWS, MIMR, MODIS-N, EOS SAR, and STIKSCAT.

Recommendations:

(1) Congruent measurements with AIRS/AMSU-A/MHS, STIKSCAT, MIMR, and MODIS-N are the highest priority. The addition of CERES would enhance this objective.

(2) LAWS and EOS SAR are priorities.

Key Objective B-3: To determine the role of the cryosphere in moisture and energy fluxes and its role in governing the atmospheric and oceanic circulation.

Critical Science Issues: Continental snow is a major seasonal storage component of the hydrologic cycle, and spring melt may be a dominant component of run-off. Snow cover contributes substantially to the annual periodicity in land surface processes and surface albedo. Sea ice plays a major role in climate through ice-albedo feedback and contributes to seasonal and interannual variability of climate. Sea ice changes may modify ocean- atmosphere heat fluxes and deep water formation.

Policy Implications: The interaction of the cryosphere with climate has a major impact on the magnitude of global climate change and the nature of climate variability. Changes in snow cover may contribute substantially to changes in water resources.

Potential for Scientific Advance: In many regions, ground-based observations do not exist. Accurate data on snow and ice characteristics, in addition to distributional characteristics in conjunction with atmospheric measurements, would substantially increase our knowledge of the role of the cryosphere.

Science Needs: The primary science needs are: (a) snow extent, depth, and water equivalent; (b) sea ice extent, concentration, and thickness; (c) the nature of seasonal and interannual variability; and (d) synergistic measurement of atmospheric conditions (temperature and moisture profiles).

EOS Instruments: The following instruments will aid substantially in addressing these needs: AIRS/AMSU-A/MHS, CERES, HIRIS, MIMR, MODIS, and EOS SAR.

Recommendations:

(1) MIMR, MODIS-N, and HIRIS are essential instruments for snow and sea ice data products.

(2) AIRS/AMSU-A/MHS and CERES would contribute to understanding climate-cryosphere interaction.

(3) EOS SAR is a high priority.

Recommendations with Reference to the "Seattle" Payload *

Morning orbit	Afternoon orbit
ASTER (with HIRIS on 2nd platform)	AIRS/AMSU-A/MHS
MISR	CERES
MODIS-N	MIMR
SAGE III	MODIS-N
MOPITT	HIRDLS

The priorities of the Panel are largely achieved with the "Seattle" payload with the exception of the following issues:

The Priority (A-3) objective is not satisfied at all, despite its significance, without the incorporation of GLRS-A.

Priority (A-1)	Goals would be enhanced by LAWS, EOS SAR, and LIS.
Priority (A-2)	Goals would be enhanced by LAWS and STIKSCAT.
Priority (B-1)	Goals would be enhanced by EOS SAR and LAWS.
Priority (B-2)	Goals would be enhanced by STIKSCAT.
Priority (B-3)	Goals would be enhanced by EOS SAR.

Recommendations:

(1) GLRS-A should be included in the modified "Seattle" payload.

(2) Lack of global wind measurements is a serious limitation in quantifying and understanding the hydrologic cycle. LAWS and STIKSCAT are high priority instruments and should be maintained as candidate instruments should budgets permit.

(3) EOS SAR should be strongly supported as part of Mission to Planet Earth. ❑

* The "Seattle" Payload was introduced for further consideration at the meeting of the EOS Investigators Working Group in Seattle, Washington in August 1991.

Calibration

Bruce Guenther
EOS Project Scientist for the Observatory

This meeting was held in Baltimore, Maryland, October 24-27, 1991. The VIS-NIR and thermal infrared working groups met on the first day. The VIS-NIR WG reviewed the wavelength and field-of-view requirements for instrument cross-comparison, and the benefits of round-robin metrology-scale comparisons compared to cross-comparisons to be performed at the spacecraft integrator's facility. Discussions of candidate surfaces for flight-reflective diffusers included a review of Spectralon™. The thermal infrared WG also concentrated on techniques for laboratory metrology-scale comparisons and cross-calibrations during the integration process. The planning for the laboratory-scale comparisons includes a set of radiometers under development by the Optical Sciences Center, University of Arizona, and the ASTER team from Japan. The U.S. National Institute of Standards and Technology also may build some hardware for this work and will administer the measurements program.

A briefing on spacecraft accommodations was presented by Nick Koepp-Baker, but events have overtaken virtually all the material presented there.

Mous Chahine, the Panel Chairman and AIRS Science Team Leader, led a discussion of Data Product Validation. This topic will be covered at the next Panel meeting (see following article on Data Product Validation). Guenther discussed plans for the Peer Review Process.

The final day and a half involved briefings from the national standardizing laboratories of the U.S., U.K., Japan, and Canada. These talks were designed to present to the panel members the capabilities of these national labs as they might apply to and be used for calibrations in the EOS program.

The next Calibration/Data Product Validation Panel meeting is scheduled for April 6-10, 1991 in Boulder, Colorado. ❑

Data Product Validation

Mous Chahine, Chair

Data Product Validation is critically important to the scientific goals of the EOS Mission. By validation we mean "developing a quantitative sense for the physical meaning of the measured parameters," for the range of conditions under which they are acquired. This is a scientific research topic requiring a deep understanding of both the measurement technique and the physics of the derived quantities. Through a validation effort, we expect to discover the strengths and weaknesses of data sets. The assignment of "error-bars" and caveats on many aspects of archived EOS data, the main product of validation, is essential if the data is to be quantitatively useful.

At the next meeting of the EOS Calibration and Data Product Validation Panel, we will begin to develop an EOS Data Product Validation policy and discuss approaches to optimizing the funding and research efforts that will be ongoing in validation. The panel meeting is scheduled for the week of April 6, in Boulder, CO and will focus on validation issues the final two days of the meeting. Presentations from Interdisciplinary Investigators, Instrument Science Teams, and Project Staff will include an assessment of the current status of validation, a look into support for validation from the EOSDIS, and discussion of some currently planned EOS field campaigns.

EACH INVESTIGATION, instrument or interdisciplinary, is asked to name a representative from the Investigation, as liaison to the panel for validation. The names of these representatives are to be sent to Bruce Guenther, Code 920.1, NASA/GSFC, (301) 286-5205. Further information on this meeting can be obtained from the meeting coordinator, Jan Hostetter, Birch and Davis, (202) 479-0360, or from Guenther. A final agenda will be sent in early March. ❑

THE EARTH OBSERVER

The Earth Observer is published by the EOS Project Science Office, Code 900, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, telephone (301) 286-3411, FAX (301) 286-3884. Correspondence may be directed to Charlotte Griner at the above address. Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the meeting calendar should contain location, person to contact, and telephone number. To subscribe to *The Earth Observer*, or to change your mailing address, please call Linda Carter at (301) 513-1613, or write to the address above.

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SCIENCE TEAM MEETING

MODIS Science Team Meeting Unveils MODIS-N

Steve McLaughlin
MODIS Administrative Support Team

A MODIS Science Team meeting was held at Goddard Space Flight Center on October 1-3, 1991. Two principal themes prevailed during the meeting—the public unveiling of the instrument design for MODIS-N, and the need to respond to recent significant changes in the scope and budgeting for the EOS program. The high level of interest in the program agenda that addressed these themes resulted in an active, productive, and well-attended meeting. Over 100 participants joined to discuss MODIS, including all of the Science Team members or their selected representatives.

Vincent Salomonson, MODIS Team Leader, opened the meeting by reviewing the events of the busy summer. In addition to escalating activity associated with MODIS and SeaWiFS, Earth scientists have seen the launches of UARS and TOMS. Salomonson summarized the objectives he hoped the team members would address during the meeting. The first objective was consideration of several changes in MODIS-N specifications. Another objective was to search for compelling arguments to support MODIS-T, and the impact of its possible deselection. The Seattle IWG meeting placed investigators in the position of descoping EOS, leaving the future of MODIS-T in doubt. Investigators were asked to consider the scientific ramifications of flying MODIS-N on a morning and on an afternoon platform, a possible scenario also introduced in Seattle.

Shelby Tilford, Earth Science and Applications Division Director, gave a presentation on recent activity associated with the EOS payload selection process and the anticipated effects on MODIS. He discussed the budgetary and political factors involved and projected ramifications for EOS science. He also spoke about the expanded role in the field of Earth sciences for sister agencies to NASA such as the EPA, DoE, DoD, and NSF. After his prepared presentation, the floor was opened to questions. A highly informative series of exchanges dealt with issues like specifics of the program's interactions with Congress, Landsat, and foreign space agencies, NASA's public image, political pressures for a launch, conflicts between DoD's need for security and the desire of scientists for open communications, and ways to most directly achieve measurements of global change.

Jeff Dozier presented the Project Science Office report. He outlined his interpretation of the results of the Seattle IWG meeting. A result of the Seattle meeting was that MODIS-T may be deselected from the EOS platform. Dozier emphasized that MODIS investigators should search for ways to compensate for the loss of MODIS-T. He also asked that investigators seriously consider less expensive alternatives to MODIS-N on either the morning or afternoon platform. In a question-and-answer session, concerns about DoD involvement were again voiced, as well as the burden of the "teething pain" investigators have been experiencing during the initial stages of implementation of their 10-year MODIS contracts.

A series of technical presentations followed the morning's overviews. The GSFC Project Engineer for MODIS-N, Richard Weber, introduced Jack Engel of Santa Barbara Research Corporation (SBRC). SBRC has been awarded the contract to construct MODIS-N. Engel presented the first technically detailed public presentation of how MODIS-N will be built. This event has been awaited with high expectations by the Science Team. For most it was also their first view of the instrument. William Stabnow, GSFC Project Manager for MODIS-T, followed with a talk on the status of MODIS-T development. He addressed the progress that has been made on the instrument, and some of the design techniques that have been employed. The program is entering into a holding pattern for MODIS-T hardware and personnel until a firm decision is made on the disposition of MODIS-T and its resources.

Rick Bredeson presented the EOSDIS Project status report. His talk dealt with the overall context of the ground system and the approaches they are developing to deal with the prodigious quantities of data expected from MODIS and other EOS instruments. Bredeson presented a milestone schedule, outlined the program core system, showed the project organization and personnel already in place, and discussed a software tool kit under development for investigators.

The first day of the meeting was concluded by allowing the four discipline group leaders to present the agenda that they wished to pursue during the discipline group meetings. They each distributed a brief list of interdisciplinary issues and action items that they requested their fellow group leaders to address. The following day was devoted to discipline group meetings, as described below, and ended with a catered evening social.

Atmosphere Discipline Group

Under the direction of group leader Mike King, data from AVHRR, VIRSR, and MODIS-T were considered as substitutes for having MODIS-N on one of the EOS platforms. None of these instruments comes reasonably close to satisfying the needs of the atmospheric scientists, and it was concluded that no scientific justification for a substitution exists. It was decided to recommend inclusion of the GLRS-A laser altimeter in the EOS program because it was considered to be a good complement to existing cloud sensors. The Atmospheric Group attended a joint presentation with the Land Discipline Group on MISR. The abilities of MODIS-N, MISR, and EOSP to study atmospheric aerosols were later discussed. Didier Tanre presented the results of polarization observations he has conducted near La Crau, France. MISR was preferred over both other instruments. King also presented a detailed status report on the MODIS Airborne Simulator (MAS), which is being prepared and tested at Daedalus, Inc. The contractor is moving rapidly to prepare for November flights with the MAS on the ER-2 aircraft. MAS will be only partially operational during these flights, with fully capable flights scheduled for June 1992. The group found acceptable the MODIS-N specification changes and the proposed morning and afternoon MODIS-N orbits, discussed the difficulties inherent in evaluating instrument costs, and recommended gain changes for several of the MODIS-N data channels.

Calibration Discipline Group

Work by the Calibration Discipline Group was coordinated by Group Leader Philip Slater. The MODIS Calibration Panel met for a full day prior to the MODIS Science Team meeting, and therefore did not meet during the regularly planned meeting session. This permitted John Barker to visit each of the Discipline Groups during their individual sessions to address individual needs and questions with respect to calibration. Slater presented a report of their proceedings during the final Science Team plenary session. Topics of discussion included specific plans for MODIS-N and MODIS-T calibration, image simulations using Landsat TM data, sensor modeling, MAS calibration, solar variability studies, and pre-, post-, and cross-calibration plans.

Land Discipline Group

The Land Discipline Group devoted a significant amount of time to issues related to a comparison of MODIS-T and MISR. Group leader Chris Justice orchestrated the presentation of a variety of arguments pro and con for both instruments, all of which were geared to the needs of the land group. Both MODIS-T and MISR were found to have appealing strengths, but the final decision was in favor of MISR. Benefits of having MODIS-N on both a morning and an afternoon platform were noted, resulting in the land group strongly endorsing MODIS-N on both platforms. Land investigators expressed a need for high-resolution data to support MODIS-N validation and testing, and identified ASTER and HIRIS as good sources of such data. Other lower resolution testing sources might be found in the EDC DAAC data bases and reference data bases like 1 km resolution AVHRR data. There was a strong push to achieve maximum accuracy on image registration capability. Interdisciplinary reports from the Atmosphere Discipline Group regarding the atmosphere's effects on land sensing, vegetation indices, and cooperative MAS measurements were presented by Yoram Kaufman and Mike King. The session was completed with reports by each investigator on their recent field experiments. These included work by Dorothy Hall in Glacier National Park, Alfredo Huete in Arizona and in Niger, Phillip Teillet in Canada, Alan Strahler's Chinese collaborations, and Mike Barnsley's computer simulations.

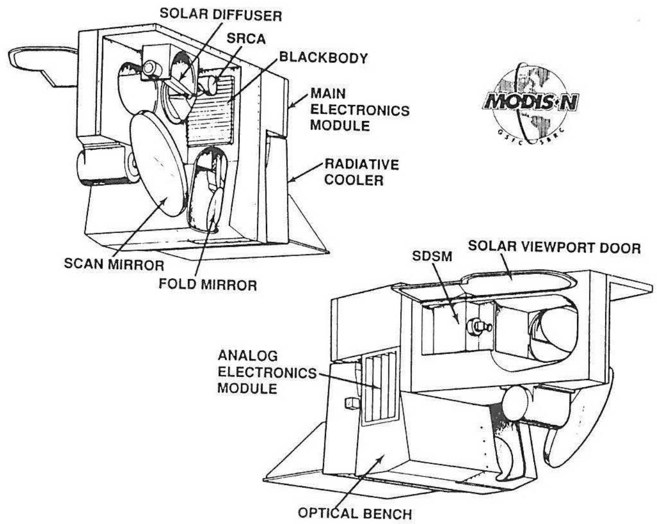
Ocean Discipline Group

MODIS-N specification changes were first on the agenda for the Ocean Discipline Group, chaired by Wayne Esaias. The group also added their own changes to coordinate MODIS band modifications with similar changes made for SeaWiFS. Contractual cross-obligations exist between MODIS and SeaWiFS, and the investigators discussed coordination of funding and personnel. The related issues of orbits for the EOS platforms, sunglint patterns, orbit coverage, and the limitations placed on coverage by cloud cover patterns were discussed. Variations in the capabilities of SeaWiFS 2 were debated, as well as data rights for Orbital Sciences data. Mark Abbott presented a report on the deliberations of the Oceans Panel at the Seattle IWG. MODIS-T is ideally suited for oceans studies, and the oceans investigators feel its loss will impair their ability to achieve the science they have been tasked to do. Other sensors like HIRIS and SeaWiFS are considered helpful, but the Oceans Panel is staunchly behind placing MODIS-T on an EOS platform. If MODIS-T is not on EOS, the group felt it should fly on some other platform, with additional efforts made to keep the calibration and validation consistent. They considered alternative data sources in the event that MODIS-T is deselected. A strong desire was expressed to achieve a coherent program of long-term continuous monitoring of the oceans.

Science Data Support Team

Al Fleig visited each of the Discipline Groups during their individual sessions. He briefed them on the current activities and planned responsibilities of the Science Data Support Team (SDST). The topic of greatest interest was the Team Leader Computing Facility, a MODIS-devoted computer facility that will be used by the investigators for algorithm development and validation. Plans for the TLCF are still being formulated, and interfaces to the investigators are quite flexible. Fleig expressed a desire to have the TLCF help set the standards for creation of EOSDIS. SDST will also act as a liaison between the investigators and EOSDIS, and will assist with data quality and software documentation. Fleig presented an overview of the plans for SDST data processing. In addition, he clarified use of the software tool kit which will be provided by the Project to investigators, and discussed the role SDST will play in image registration.

The final day of the MODIS Science Team meeting was devoted to a summary by each of the four discipline group leaders of issues they had discussed. Salomonson gave a closing address, in which he thanked the team for their cooperative, professional, and thorough treatment of the volatile issues on the table during the meeting. He remarked on the outcome of two significant issues: the sentiment regarding MODIS-T and specifications changes for MODIS-N. While the Ocean Discipline Group still expressed a strong desire to fly MODIS-T, they did address caveats in the event it isn't available. The Atmosphere Group prefers MISR over MODIS-T, and the Land Group has a qualified preference for MISR. No major obstacles were encountered in MODIS-N specification changes, with the uncertain possible exception of image registration at the focal plane. The next Science Team meeting has tentatively been scheduled for mid-April 1992. ❑



Atmospheric Infrared Sounder

George Aumann

The EOS Payload Advisory Panel has identified the energy and water cycles as the highest priority science and policy issues for EOS. This defines temperature and humidity measurements on a global scale as the key data sets provided by EOS. The Atmospheric Infrared Sounder, AIRS, together with the Advanced Microwave Sounding Unit (AMSU-A) and the Microwave Humidity Sounder (MHS), provides these data sets globally and over a long time span. Specifically, AIRS/AMSU-A/MHS provides global day and night:

- Atmospheric temperature profiles with an average accuracy of 1° C in 1 km thick layers in the troposphere;
- Relative humidity profiles with an accuracy of 10% up to the tropopause and total precipitable water vapor with an accuracy of 5%;
- Fractional cloud cover, and cloudtop pressure and temperature; and
- Land and sea surface temperature with an average accuracy of 1 degree C for land, 0.5 degree C for sea.

In addition to these core products AIRS/AMSU-A/MHS provides data on a number of other research products such as land infrared emissivity and albedo, total ozone burden of the atmosphere, mapping of the distribution of minor atmospheric gases such as ozone, precipitation index, snow/ice characterization, cloud characterization, and surface scalar wind speed over oceans.

The three instruments form a complementary sounding system on EOS. The global climate monitoring data obtained from EOS will be extended well into the 21st century with AIRS/AMSU-A/MHS copies on the NOAA and EUMETSAT operational weather satellite systems.

The AIRS instrument is a grating array spectrometer that covers the spectral region from 3.4 to 15.4 μm contiguous in about 3600 channels with a spectral resolving power ($\lambda/\Delta\lambda$) of 1200. AIRS also contains low-spectral-resolution visible light channels. AIRS employs 49.5 degree cross-track scanning with a 1.1 degree instantaneous field of view (IFOV) to provide twice daily coverage of essentially the entire globe from a 705 km altitude, on a 1:30 p.m., sun-synchronous orbit. The AMSU-A and MHS are synchronized with AIRS and have the same spatial coverage, with IFOV of 3.3 and 1.1 degrees respectively. AMSU-A has 15 channels between 50 and 90 GHz; MHS, formerly known as AMSU-B, has five channels between 90 and 183 GHz. The two microwave instruments will first be flown in polar orbit on NOAA K, L, M starting in 1995.

The AIRS science team and representatives from NOAA and the USAF met on November 4 and 5, 1991 at the Goddard SpaceFlight Center to review the status of the hardware and the science data algorithm development.

1. AIRS Hardware Development.

The contract for the AIRS instrument was awarded to LORAL Infrared Imaging Systems (LIRIS), located in Lexington, MA, on March 15, 1991. A very successful Systems Requirements Review (SRR) was held in Lexington on October 29 and 30, 1991. The purpose of this meeting was to insure that the science measurement requirements stated in the AIRS Functional Requirements Document (FRD), were understood by LORAL. Except for minor clarifications, which have been incorporated into the FRD, all requirements were understood.

During the phase B study of the program the development of the AIRS detectors and associated coolers were identified as key technology areas requiring early technology demonstrations. To meet the required temperature sounding accuracy, the AIRS spectral radiance measurement noise cannot exceed the equivalent of NEΔT=0.2 degree RMS. This can be achieved only with very good detectors operating at 60 K temperature. Results from these two areas were presented following the SRR:

a) Detector operation at 60 K requires 1.2 watts of cooling capacity at 55 K to be provided by two coolers for five years, i.e., 0.6 watts per cooler. This capacity compares to 0.4 watt at 80 K for coolers currently on the UARS and IRTS spacecraft. Two study contracts were competitively placed with industry to demonstrate this capability: British Aerospace and Lockheed-Lukas. Both companies by now have tested engineering models of refrigerators with 0.82 watt and 0.88 watt cooling power at 55 K, respectively. This exceeds the requirement with an adequate margin. The cooler issue is thus considered a design issue and not a technology issue.

b) The baseline design AIRS uses HgCdTe detectors operated in the PC (photoconductive) or PV (photovoltaic) mode. NEΔT performance was nominally achieved with PV detectors short, and with PC long of 13.6 microns. This hybrid focal plane is still the current baseline, but the use of PV detectors at all wavelengths was considered a highly desirable feature. Tests of PV detector material designed and grown specifically for the AIRS 13.6 - 15.4 micron region look very promising. Results from tests of arrays made from this material are expected by the end of the year.

2. AIRS Science Data Algorithm Development

The AIRS/AMSU-A/MHS temperature and moisture retrievals are the core AIRS science data product. This retrieval, based on the simultaneous solution from AIRS, AMSU-A, and MHS channels, is expected to be computationally intensive. The AIRS data system development distinguishes between the core algorithm and research algorithm development. Stringent requirements on accuracy of the data, the need for timeliness of the data production to be useful for weather forecasting, and the interest of NOAA in AIRS as an operational sounder give the core data product very high visibility. For this reason the core algorithm development is proceeding along parallel tracks by different teams using different concepts. The final algorithm will be selected by the team leader, based on the lessons learned and combination of these algorithms. A Data Processing and Instrument Operations (DPIO) team has been established at JPL to support the team leader in this function. The DPIO team will supply simulated data, including AIRS instrument simulations with increasing fidelity, in support of the core algorithm development. The first delivery of simulated data is expected by April 1992.

A) The Goddard algorithm, developed by Joel Susskind, is a physical retrieval using an iterative relaxation method based on the extension of the algorithm currently used for processing the HIRS2/MSU data at GSFC. The algorithm meets the AIRS retrieval accuracy requirements based on GSFC data simulation and is ready for testing with JPL-supplied simulated data.

B) The University of Wisconsin algorithm, developed by William Smith, uses a linearized form of the radiative transfer equation and matrix inversion. The algorithm is ready for testing with JPL-supplied simulated data.

C) The NOAA algorithm, developed by H. Fleming, is a statistical/physical minimum-variance matrix inversion. It is an extension to the current NOAA operational retrieval algorithm used with HIRS2/MSU data. The algorithm will be ready for testing with JPL-supplied simulated data by April of 1992.

D) The algorithm developed by A. Chedin (France) is an extension of the algorithm used for HIRS2/MSU analysis. It is an iterative physical retrieval with a first guess based on pattern recognition. Use of JPL-simulated data for the evaluation of this algorithm is currently under evaluation.

E) The Phillips Laboratory (formerly AFGL, J. King) is pursuing a computationally very efficient algorithm based on zeta function transformations. Prototype tests with HIRS2/MSU data look promising.

AIRS will, as byproducts of the core data or independently, produce a large number of research products, including land infrared emissivity and albedo, total ozone burden of the atmosphere, mapping of the distribution of minor atmospheric gases methane and CO, precipitation index, snow/ice characterization, cloud characterization, energy balance, and surface scalar wind speed. Specific algorithm concepts, currently under exploration or development, were presented at the meeting for the following products:

a) The concept for radiation balance (Catherine Gautier, University of California, Santa Barbara) was presented by collaborator Robert Frouin of Scripps Institution of Oceanography.

b) The algorithm presented by Hank Revercomb, University of Wisconson, uses linearized operators to retrieve minor constituents. The algorithm development currently uses data from an airborne infrared interferometer with wavelength range and resolution comparable to that of AIRS. In addition to total ozone, CH_4, and CO burden, the possibility of sensitivity to tropospheric ozone in areas of heavy pollution is under evaluation.

c) Larrabee Strow, University of Maryland, Baltimore, showed promising results with simulated AIRS data and an FFT covariance algorithm for the retrieval of CO and CH_4.

d) William Smith, University of Wisconsin, presented concepts for direct retrieval of cloud properties, in particular cirrus clouds, using combined AIRS/ MODIS-N data.

e) M. Chahine, Jet Propulsion Laboratory, discussed cloud-characterization concepts using output of the core algorithm cloud-clearing algorithm.

f) R. Rizzi, University of Bologna, Italy, is working on a cloud-clearing algorithm. He showed that fractional cloud cover currently derived operationally from HIRS/MSU data is inconsistent with cloud data from the AVHRR.

g) Phil Rosenkranz, Massachusetts Institute of Technology, provided details for the derivation of the initial temperature profile using AMSU-A data only and the humidity profile and cloud liquid water retrieval from AMSU-A and MHS data.

h) David Staelin, Massachusetts Institute of Technology, presented an algorithm approach to deduce cloud liquid water content and land/sea snow/ice cover from AMSU-A and MHS data.

i) H. Aumann, Jet Propulsion Laboratory, presented a sea state evaluation algorithm based on 53 and 90 GHz emissivity and 11 micron surface temperature data. Data from AMSU-A/B and HIRS2 on NOAA K, to be launched in 1995, will contribute to the development of the algorithm. ❑

TOPEX/POSEIDON Mission

Lee-Lueng Fu
Michel Lefebvre

In the summer of 1992, TOPEX/POSEIDON, a satellite mission jointly conducted by the U.S. National Aeronautics and Space Administration (NASA) and the French Centre National d'Etudes Spatiales (CNES), will deploy a state-of-the-art altimetry system into an orbit configured to measure global sea level for the study of ocean circulation. Although prior altimetric missions have been used to study the ocean circulation, TOPEX/POSEIDON is the first one designed for that purpose. As part of NASA's Mission to Planet Earth, TOPEX/POSEIDON will study the large-scale movement of currents of the global oceans which modulate the Earth's climate by redistributing heat from the equatorial to the polar regions, as well as the ocean's coupling with the atmosphere during strong climatic variations such as the El Niño Southern Oscillation phenomenon.

The primary instrument suite consists of a dual-frequency (13.6 and 5.3 GHz) altimeter that can retrieve ionospheric range correction, a microwave radiometer for tropospheric range correction due to water vapor, a radiofrequency satellite tracking system called DORIS, and a laser retroreflector array for satellite tracking and altimeter calibration. Also carried onboard are two experimental sensors: a solid-state altimeter (13.6 GHz) for validating light-weight, low-power altimetry technology and a Global Positioning System (GPS) receiver for validating a new precision satellite tracking system. All of the instruments have been integrated into a modified Multi-Mission Modular Spacecraft by Fairchild Space, the mission's system contractor. The integrated system is currently in its final stage of testing and is targeted for launch by an Ariane-4 rocket at Kourou, French Guiana, in July of 1992. *For more information on the mission the reader is referred to Fu et al. (1991) and the TOPEX/ POSEIDON Mission Design Team (1991).*

After launch into an orbit with a 66-degree inclination at a 1336-km altitude with a 10-day repeat period, the mission will enter a calibration phase of about 6 months, during which the measurement system will be calibrated and validated via a global campaign conducted by the project engineers and the mission's Science Working Team (SWT), a team of 38 Principal Investigators selected to conduct scientific research using the mission's data. The primary calibration sites are located at Point Conception off California and Lampedusa in the Mediterranean Sea. Following calibration, the data stream will be released to both the SWT and the general public.

The members of the SWT will use the data to conduct research in ocean circulation, ocean tides, and marine geophysics (see TOPEX/POSEIDON Science Working Team, 1991). The main objective of the mission — ocean circulation — is the focus of 29 Principal Investigators. Among other objectives, they will produce the following two products that will be most beneficial to the goals of global change studies: (1) a multi-year data set of global sea level with an unprecedented accuracy, and (2) a long-wavelength (greater than 4000 km) geoid model useful for ocean circulation studies. The highly accurate observations of the global sea level variations will yield an increased understanding of the global ocean dynamics. The combination of the sea level data with the geoid model will allow one to derive the long-wavelength components of the absolute circulation that are particularly difficult to estimate from *in-situ* measurements. Within the SWT there is a strong modeling group committed to assimilating altimetry data into ocean models to study the roles of ocean in climate.

The SWT recently had its fourth meeting in Toulouse, France, October 22-25, 1991. A major focus of discussion was the accuracy with which the orbit can be determined. Uncertainty in orbit radius is the largest error source in the TOPEX/POSEIDON measurements. The French DORIS tracking receiver, which is part of the TOPEX/POSEIDON orbit determination system, has recently been demonstrated by the SPOT-2, mission. The performance of the SPOT-2 DORIS receiver was thoroughly reviewed in a workshop preceding the SWT meeting. This 2-frequency Doppler system has proven to be a powerful system for satellite tracking and gravity model improvement. Given the relatively low altitude (800 km) of SPOT-2, where the atmospheric drag is severe for orbit determination, a 20-cm orbit accuracy has been achieved. The tracking data has also greatly improved the gravity model that will benefit orbit determination for the ERS-1 satellite, which is flown at an inclination similar to SPOT-2.

The higher altitude of the TOPEX/POSEIDON satellite will ensure a much smaller atmospheric drag and an increased coverage by the ground tracking stations; consequently, the utility of the DORIS system for TOPEX/POSEIDON will be greatly enhanced. It is anticipated that the combination of DORIS and laser ranging can achieve the long-awaited goal of sub-decimeter orbit accuracy.

Also reviewed in the meeting were methodologies for orbit error reduction using additional constraints imposed by altimetry data. These approaches will probably be able to bring the orbit error down to a level below 5 cm eventually. With this level of accuracy, it is anticipated that many of the questions regarding basin-scale ocean circulation and its role in global change can be addressed.

To maximize the science return from TOPEX/POSEIDON and also lay the foundation for future EOS programs in monitoring the global ocean circulation and sea level changes, the SWT has made the following recommendations:

1. To ensure that the orbit radius in the TOPEX/POSEIDON Geophysical Data Records has the highest quality possible, the SWT strongly urges that the orbit should be computed by using all tracking data simultaneously —both U.S. and French in origin.

2. A gravity mission from a low-altitude satellite such as ARISTOTELES (a proposed joint European-U.S. mission) is the only feasible approach to obtaining a precise geoid for determining the absolute ocean topography from altimetry at wavelengths down to 200 km. The SWT strongly urges the flight of the ARISTOTELES mission as early as possible.

3. Given the great potential of the GPS system in optimizing the accuracy of the TOPEX/POSEIDON orbit and in demonstrating a powerful tracking system for the future, the SWT strongly urges that the GPS system be evaluated as soon as possible after launch and that provision of funding be established to

process all the collected data for routine orbit computation if the system is proven successful.

4. To ensure a continuous data stream of precise global sea level observations to address the global change problems, the SWT strongly urges that the international space agencies begin planning a TOPEX/POSEIDON follow-on mission. A white paper summarizing the main conclusions from a group of scientists and engineers has been prepared and endorsed by the SWT.

5. Precise knowledge of the atmospheric wind and pressure fields is important for interpreting the altimetry observations. The SWT strongly urges that the international weather forecast centers utilize the ERS-1 scatterometer data and/or surface drifters to improve the analysis of sea surface wind and pressure fields.

6. The SWT recognizes the importance of the WOCE/TOGA sea level gauges to the calibration of TOPEX/POSEIDON measurements and strongly urges that an upgraded data processing and transmission system be established such that the sea level data can be available to TOPEX/POSEIDON investigators with delays not exceeding two months. It also strongly recommends that geodetic links between the sea level gauges and the satellite tracking stations be established.

7. The SWT recognizes the potential benefits of TOGA/COARE and the planned SEMAPHORE Program (a French initiative) to the calibration/validation of TOPEX/POSEIDON measurements and strongly urges that international oceanographic agencies provide support to these two programs.

8. To facilitate the merging of ERS-1 and TOPEX/POSEIDON data, the SWT urges that cross-calibration between TOPEX/POSEIDON and the ERS-1 altimeter be performed when ERS-1 overflies the Lampedusa site after April, 1992 during the 35-day repeat orbit. Along the same line, use of multiple crossovers from the two missions will enhance their mutual benefits.

9. To compute a better mean sea surface, the SWT strongly endorses that ERS-1 should be placed in the 176-day repeat cycle as specified in the mission plan.

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The Advanced Solid-State Array Spectroradiometer (ASAS)

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INTRODUCTION

Several of the instruments originally selected for EOS were proposed with off-nadir tilting capabilities. They included MODIS-T, HIRIS, and MISR. An important reason for this proposed capability was to sample the angular distribution of solar radiation scattered from Earth's surface. The intent was to better characterize Earth surface bidirectional reflectance distribution functions (BRDFs). In advance of the EOS era, the Laboratory for Terrestrial Physics at NASA/GSFC has modified an airborne sensor for off-nadir tilting. The sensor is called the Advanced Solid-State Array Spectroradiometer (ASAS).

ASAS is an airborne, off-nadir tilting, imaging spectroradiometer that acquires digital image data for 29 spectral bands in the visible and near-infrared. The spectral channels span the 465 nm to 871 nm wavelength region with a spectral resolution of 15 nm. The sensor is used primarily for studies of the angular distribution of reflectance from terrestrial targets, as it is capable of viewing and tracking a target area through a sequence of view directions (45° forward to 45° aft) while its platform aircraft flies over the area. ASAS has been involved in a number of terrestrial ecosystem field experiments, and over 150 scenes of data have been radiometrically corrected and delivered to principal investigators. An ASAS data scene typically consists of seven sub-images, each acquired from a different view direction, and the data are delivered in units of absolute at-sensor spectral radiance.

Irons et al. (1991) have described ASAS and its initial multi-angle data products. Updated descriptions of the sensor, its operation, and its data products follow. Discussions of ongoing sensor upgrades and the dissemination of ASAS data to data information systems are also included.

History

ASAS has evolved over a number of years. The optics were originally part of the Scanning Imaging Spectroradiometer (SIS) built in the early 1970's for NASA/JSC. SIS employed a vidicon detector for imaging. ASAS was created in 1981 when a charge-injection-device (CID) detector array was incorporated with the optical system for a cooperative program involving NASA/JSC and the Naval Ocean Systems Center. The sensor was transferred in 1984 to NASA/GSFC where the aircraft mounting bracket was modified to permit off-nadir tilting. The tilting capability was first utilized in 1987 for the First ISLSCP (International Satellite Land Surface Climatology Project) Field Experiment (FIFE) (Sellers et al. 1988).

Sensor Description

Radiation incident on the ASAS aperture is focused onto an entrance slit by an f/1.4 objective lens that provides a 25° cross-track field of view. The radiation is relayed through a transmission grating that disperses the radiation across the spectral dimension (29 rows) of the 512-by-29-element silicon CID detector array. The long dimension of the array is reserved for the resolution of 512 cross-track ground elements. The cross-track spatial resolution is 4.25 m from an altitude of 5000 m.

The sensor is operated in the "pushbroom" mode to produce digital image data. The signals generated by the CID detectors are sampled at a rate of 48 scan lines per second to produce the along-track dimension of the digital imagery. The sampled signal from each detector is digitized to 12 bits and the digitized signals are stored in a pulse-code-modulated format by an on-board high-bit-rate tape recorder.

The ASAS optical head is mounted to its platform aircraft by a bracket with a gimbal (Fig. 1). The optical head sits in an open port with no window. The gimbal permits off-nadir tilting of the optical head up to 45°

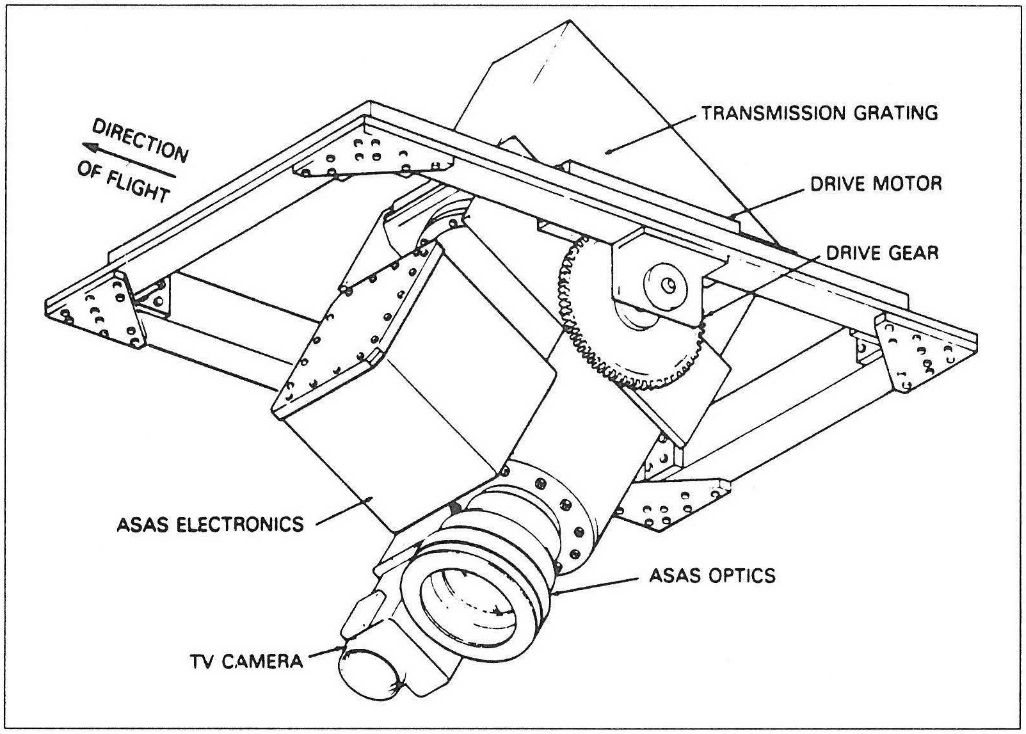

Figure 1. The NASA optical head and aircraft mounting bracket.

either fore or aft. A video camera is mounted with the optical head to relay a picture to an on-board television screen at the ASAS operator's station. The television picture allows the operator to locate and track a target site through a sequence of view directions. The operator tracks a site via microcomputer control of an electric motor that rotates the optical head about the gimbal.

Data Acquisition

The ASAS tilting system was first tested aboard the NASA/Wallops Skyvan and has since flown aboard the NASA/ARC C-130 for field experiments. ASAS data have been acquired over a variety of terrestrial ecosystems in support of a number of projects: the Konza Prairie, Kansas, for FIFE (1987 and 1989); Northern forests in Minnesota (1988) and Maine (1989 and 1990) for the Forest Ecosystem Dynamics (FED) project; gypsum sand dunes in White Sands, New Mexico, for a sensor calibration experiment (1988); the Lunar Lake Playa, Nevada, for the Geologic Remote Sensing Field Experiment (GRSFE) (1989), Northwestern forests for the Oregon Transect Ecosystem Research (OTER) project (1990); agricultural fields and orchards in Maricopa, Arizona, for a BRDF experiment (1991); snow-covered fields in Glacier National Park for a MODIS team investigation (1991); and semi-arid vegetation and soils in Walnut Gulch, Arizona, for a MODIS team investigation (1991).

Investigators usually request multi-angle data from ASAS. To obtain such data, the sensor field-of-view is tilted forward as the aircraft approaches the target site. The optical head is then rotated through a discrete sequence of fore-to-aft tilt angles as the aircraft flies over and then past the site. A typical sequence consists of seven angles from 45° forward to 45° aft in 15° increments. The sensor acquires several hundred scan lines of data at each tilt angle depending on aircraft speed and altitude. This approach acquires data for multiple-view zenith angles along a single-view azimuth. To acquire data for multiple-view azimuth angles, investigators often request multiple flights over a site along headings perpendicular, parallel, and oblique to the solar principal plane. Flights have also been made along the solar principal plane with ASAS tilted in the anti-solar direction for observation of the vegetation "hot spot" or opposition effect.

Calibration

An emphasis has been placed on sensor calibration and the radiometric correction of ASAS data. Spectral and radiometric calibration data are acquired in the laboratory since in-flight reference sources are not currently available. The facilities of the GSFC Standards and Calibration Office are employed. Calibration data acquisition is repeated as often as the flight schedule allows to check the stability of instrument response. A monochromator is used to determine the relative spectral response of each ASAS channel. Near-monochromatic (1.7 nm bandwidth) illumination is relayed through the ASAS optics and focused on a column of detectors. The response of each detector in the column is recorded as the wavelength is varied by adjustment of the monochromator diffraction grating.

An integrating hemisphere 1.2 m in diameter serves as the radiometric reference source for ASAS. 12 tungsten filament lamps are mounted internally and baffled. 12 intensity levels are provided for sensor calibration by turning on one lamp at a time. The intensity of the radiation emanating from the hemisphere port is determined by the Standards and Calibration Office as a function of wavelength in units of spectral radiance.

For calibration, ASAS views the hemisphere port, and the digitized responses of each ASAS detector to the 12 levels of intensity are recorded. A dark-level response is also recorded. A third-order polynomial radiometric response function is then fit to the calibration data for each detector by the method of least squares. The third-order polynomial expresses digital response as a function of spectral radiance.

The radiometric response function for each of the 14,848 ASAS detectors is inverted to create a look-up table for radiometric correction of data acquired in flight. The look-up table maps the digital responses of each ASAS detector to radiance values. To create a radiometrically corrected ASAS scene, each raw ASAS datum (an integer value between 0 and 4095) is mapped to a spectral radiance value in units of $mWcm^{-2}sr^{-1}\mu m^{-1}$. The radiance values are then scaled by multiplication by a "radiometric resolution" factor, rounded to the nearest integer value, and then stored as an INTEGER*2 value in a band-sequential digital image format. The INTEGER*2 format is used to reduce data volume and for the convenience of investigators using standard digital image analysis software packages. All of the radiance values from the 512 detectors in a spectral band are multiplied by the same radiometric resolution factor, but different factors are used for different spectral bands. The different factors are used to preserve radiometric resolution or to avoid the appearance of false radiometric resolution in the processed data. Radiance values in units of $mWcm^{-2}sr^{-1}\mu m^{-1}$ can be retrieved from processed ASAS data by dividing the data from each spectral band by the appropriate radiometric resolution factor. The factors are provided in the header record for each ASAS scene.

Data Products

Over 150 radiometrically corrected ASAS scenes have been delivered to the principal investigators of the previously mentioned projects. A scene typically consists of seven sub-images, where each sub-image was acquired from a different tilt angle during one flight over a target site. The data for each sub-image are stored in a separate file in a band-sequential format. A header accompanies each file to provide site information, flight information, the spectral band centers, and the radiometric resolution factors.

ASAS scenes suffer from geometric distortion due to the tilt angles, the scan rate, and aircraft roll, pitch, and yaw. Consequently, the multiple sub-images in a scene are not registered to one another. The severity of the distortions precludes the routine selection of ground control points for registration by "rubber sheet" stretching. Attitude and location data from the C-130 navigation system are currently being evaluated for the geometric rectification and registration of ASAS data.

Data Information Systems

Several of the projects involving ASAS have produced or are planning data bases on CD-ROMs for dissemination to the scientific community. The CD-ROM data bases are being prepared by the Pilot Land Data System (PLDS) within the Distributed Active Archive Center (DAAC) at NASA/GSFC. The purpose is to make project data readily available to the community of scientists involved in terrestrial remote sensing and the development of the Earth Observing System.

The Washington University node of the Planetary Data System in conjunction with PLDS has prepared a nine volume set of CD-ROMs containing GRSFE data (Arvidson et al., 1991). Volume 9 of this set is dedicated to ASAS digital image data. The GRSFE CD-ROMS may be obtained through the Coordinated Request and User Support Office of the National Space Science Data Center at GSFC, (301) 286-6695.

Release of a data base of FIFE data on CD-ROMs is scheduled for late summer 1992. Prior to the release of these CD-ROMs, ASAS data acquired for FIFE may be obtained through the FIFE Information System by contacting James McManus at GSFC, (301) 286-3135. Release of a data base of OTER data on CD-ROMs is also planned for late summer 1992. After the release, the point-of-contact for the OTER CD-ROMs will be Gary Angelici of the NASA/ARC node of the PLDS (415) 604-5947.

In addition to the CD-ROM data bases, the establishment of an archive of ASAS digital image data has begun on the GSFC node of the PLDS. The immediate objective is to provide access to ASAS data that are not available through the CD-ROM data bases. ASAS data should be available from this archive by spring, 1992. The point-of-contact will be the PLDS User Support Group at GSFC (301) 286-9761.

System Upgrades

Two major upgrades of ASAS are well underway. One upgrade is a new system for tilting the optical head. The new system is designed to allow greater tilting angles; up to 75° forward and up to 60° aft. Fabrication has been completed and the system was tested during a C-130 flight last September.

The other upgrade involves the replacement of the ASAS detector array. A silicon charge-coupled-device (CCD) array has been selected and a new data acquisition system is being designed to accommodate the new array. The new array will allow for the acquisition of data for 62 spectral bands ranging from 400 nm to 1060 nm with a spectral resolution of 11.5 nm. The schedule calls for the installation and testing of the new array in time for the HAPEX/Sahel experiment scheduled for late August, 1992, in Niger, Africa. The sensor will likely be renamed at that time to reflect the upgrades.

Concluding Remarks

Efforts are being made to increase the availability and utility of ASAS data to the EOS and general scientific communities. Distribution of ASAS data on the CD-ROMs and the development of the PLDS archive are intended to improve access to the data. The extension of the tilting angle range, the replacement of the array, the extension of the spectral coverage, and the narrowing of the spectral resolution are intended to improve sensor performance and data value.

ASAS is NASA's only airborne sensor capable of off-nadir tilting. A major justification for continued operation of this sensor is the provision of data for the development, testing, and validation of scientific algorithms requiring multi-angle data. Such algorithms will be required to fully exploit the advanced remote sensing capabilities planned for EOS. Inquiries regarding ASAS data acquisition in support of EOS investigations may be directed to Jim Irons, Biospheric Sciences Branch, NASA/GSFC, (301) 286-8978.

Acknowledgements

ASAS is supported primarily by the Ecosystem Dynamics and Biogeochemical Cycles Branch of NASA/HQ. Support has also been received from the EOS Project Science Office.

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EOS Science Meetings

January 14-16, 1992	HIRIS Team Meeting, University of New Hampshire, Durham, NH. Contact Alex Goetz at (303) 492-5086
January 20-23, 1992	ASTER Science Team Meeting, Jet Propulsion Laboratory, Pasadena, CA. Contact Anne Kahle at (818) 354-7265
January 28-30, 1992	LAWS Team Meeting, Huntsville, AL. Contact Wayman Baker at (301) 763-8005
February 27-28, 1992	MISR Team Meeting, Pasadena, CA. Contact David Diener at (818) 354-6319
April 6-9, 1992	EOS Calibration Panel Meeting, Boulder, CO. Contact Bruce Guenther at (301) 286-5205
April 14-16, 1992	MODIS Science Team Meeting, GSFC. Contact Locke Stuart at (301) 286-6481
April 28-May 1, 1992	AIRS Science Team Meeting, Cambridge, MA. Contact George Aumann at (818) 584-2934
Spring, 1992	EOS Oceans Panel Topical Science Meeting on Air/Sea Interactions. Contact Mark Abbott at (503) 737-4045
Spring, 1992	EOS Atmospheres Topical Science Workshop. Contact Mark Schoeberl at (301) 286-5819

Global Change Meetings

January 27-31	1992 Ocean Sciences Meeting American Geophysical Union, New Orleans, Louisiana. Contact Eileen E. Hofmann, Old Dominion University, Department of Oceanography, Norfolk, Virginia 23529; phone: (804) 683-5334; FAX (804) 683-5303; Omnet: E. Hofmann.
February 10-13	International Space Year Conference on Earth and Space Science Information Systems, Pasadena, California. Contact Arthur I. Zygielbaum, Jet Propulsion Laboratory, FAX (818) 354-8333; AZYGIELBAUM on NASAMAIL or AIZ@EWOK.JPL.NASA.GOV (Internet).
February 16-17	Marine Technology Society, *Down to Earth Oceanography,* a workshop for teachers, administrators and science coordinators, Catalina Island Marine Science Center. Contact Sam Kelly (714) 758-3338.
March 4-6	1st Annual Conference on Carbon Dioxide Removal, Amsterdam, The Netherlands. Hosted by the University of Utrecht, Department of Science, Technology and Society, University of Utrecht,. Write to: ICCDR c/o KIvI, P.O. Box 30424, 2500 GK The Hague, The Netherlands.
March 18-19	The Fifth Annual Geographic Information Systems Conference at Towson State, Towson, Maryland 21204. Phone: (310) 830-2964, FAX: (301) 296-8782.
May 4-6	Second Circumpolar Symposium on Remote Sensing of Arctic Environments, Tromso, Norway. Contact The Roald Amundsen Centre for Arctic Research, University of Tromso, Breivida, N-9000 Tromso, Norway. Phone: +47 83 45 240 or Telefax: +47 83 80 705.
May 11-15	American Geophysical Union's Spring Conference, Montreal. Contact Karol Snyder,American Geophysical Union, 2000 Florida Ave. N.W. Washington D.C. 20009. Phone: (202) 939-3205, FAX (202) 328-0566.
June 15-17	First Thematic Conference on Remote Sensing for Marine and Coastal Environments: *Needs and Solutions for Pollution Monitoring, Control, and Abatement,* New Orleans, Louisiana. Contact Nancy Wallman, ERIM, Box 134001, Ann Arbor, MI 48113-4001, Phone: (313) 994-1200, ext. 3234, FAX (313) 994-5123, Telex: 4940991 ERIMARB

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